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AFFTC-TR-84-19

60,000 POUND CAPACITY EXTRACTION SYSTEM

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August 1984

Final Report

Approved for public release; distribution is unlimited.

AFFTC

AIR FORCE FLIGHT TEST CENTER
EDWARDS AIR FORCE BASE, CALIFORNIA
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE

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~~This~~ test program was conducted to determine the suitability of proposed extraction parachute subsystems to safely and reliably extract platform airdrop loads weighing from 31,500 to 60,000 pounds. The following extraction parachutes were evaluated in single and cluster of two configurations:

a. 35-foot diameter single slot (ss), ~~c.~~ 40-foot diameter R, and

b. 44-foot diameter ribbon (R), ~~d.~~ 35-foot diameter R.

Twenty-seven tests were conducted during this test program. A modified HC-130H aircraft was used as the drop aircraft except for the first test where a C-141 was used. The aircraft flew at 130 knots indicated airspeed and at pressure altitudes of 2,280 to 5,000 feet. The load weights ranged from 12,880 to 42,000 pounds. Test results indicated that a cluster of two 35 foot diameter R extraction parachutes and a 15 foot diameter drogue parachute was the most suitable combination to extract a load of 60,000 pounds.

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EXECUTIVE SUMMARY

SUBJECT

This report presents the results of the 60,000 Pound Capacity Extraction System project. Testing was conducted at Edwards Air Force Base between 5 November 1982 and 27 June 1984. During the project, 27 flights were conducted.

PROGRAM DIRECTION

The 60,000 Pound Capacity Extraction System project was established by Air Force Flight Test Center (AFFTC) Project Directive Number 82-77. The test project was conducted per AFFTC Test Plan "60,000 Pound Capacity Extraction System " dated August 1982 and revised in January 1983. The program was conducted for the U.S. Army Natick Research and Development Center (USANC-STRNC-UAS).

TEST SYSTEM CONFIGURATION

Tests were conducted using C-141A and modified HC-130H aircraft configured for airdrop.

OBJECTIVE

The objective was to determine the characteristics of various extraction systems for use with future loads ranging in weight from 31,500 to 60,000 pounds.

CONCLUSIONS AND RECOMMENDATIONS

The test objective of this project was met. The 35SS was found unsatisfactory because it was unstable behind the aircraft. The 43.5R and 40R parachutes were found unsatisfactory for present low altitude parachute extraction system (LAPES) because of the distance they dropped below the ramp of the aircraft during deployment. This would prohibit their use in a LAPES enviroment because the parachutes would drag on the ground. With proper rigging and airdrop procedures the 35R parachute performed acceptably in both low velocity and LAPES airdrops.

The installation of anti-line-snag pads minimized damage to the intermediate conveyor frame assemblies.

> 1. Anti-line-snag pads, or similar alternative should be used to minimize damage to the intermediate ramp conveyor frame assemblies when using 7.5 inch circumference rope extraction lines (page 21).

With the modified HC-130H aircraft towing a 22RS or 22RS reefed 403 inches, the turbine inlet temperature (TIT) exceeded 977 degrees C during a normal LAPES profile on relatively cool days (3-8 degrees C). Use of a 22RS or 22RS reefed 403 inches as a drogue parachute behind C-130E aircraft may be unsatisfactory because the C-130E TIT limit is 977 degrees C. Further testing is

required prior to using a 22RS or 22RS reefed 403 inches as a drogue parachute with C-130E aircraft.

When using two 35-foot nominal diameter ribbon parachutes (35R), snatch forces were higher than snatch forces obtained using standard extraction systems.

The attitude control bar (ACB) rigging shown in Figure 4 was satisfactory to restrain the ACB when using a V-bridle clevis tie of three turns of Mil-W-4088 Type XVIII (6,000 pound) nylon webbing.

> 2. The ACB should be rigged as shown in Figure 4 when using a clevis tie of three turns of 6,000 pound nylon webbing (page 21).

A V-bridle clevis tie of three turns of 6,000 pound nylon was satisfactory.

> 3. A tie of three turns of 6,000 pound nylon webbing should be used with a LAPES extraction system equipped with two 35R parachutes and a 7.5 inch circumference rope extraction line (page 27).

LAPES release distances with loads weighing between 35,000 and 42,000 pounds were longer than the release distances with standard LAPES airdrops of 31,000 pound loads. When using an extraction system with two 35R parachutes, additional distance may be needed for a LAPES zone , and/or between the release panels and the impact panels.

No restraint locks were damaged on any test. No rollers were damaged due to the weight and speed of the load during extraction.

The pilot's conclusions about the LAPES type airdrops conducted were as follows:

a. A moderate power increase was required to maintain 130 KIAS after deploying a 15RS drogue parachute. Using a 22RS drogue parachute with the aircraft flying on a four degree downward flight path, the airspeed decreased approximately 5 to 10 knots, even with a maximum power setting. The aircraft accelerated approximately one foot per second per second once in ground effect.

b. Abruptly reversing longitudinal control inputs while the load is moving aft (specifically releasing forward yoke pressure once it has been applied) can cause pilot induced oscillations which dampen quickly after the load exits.

c. Stick forces of 110 pounds were required during the LAPES airdrop with a 42,000 pound load. The stick force was applied smoothly and quickly at load first movement, reaching the forward stop within one second.

d. An unavoidable pitch up of 2 to 4 degrees with full forward yoke occurred as the load moved aft. This resulted in an unavoidable climb of 6 to 8 feet prior to load exit and may have an adverse effect on load survivability for initial wheel heights above 4 feet. (NOTE: standard LAPES wheel height is between 5 to 10 feet.) Heavy weight load rigging methods should be designed to allow for loads to survive when LAPES airdropped at wheel heights up to 20 feet and/or methods or systems should be developed to allow the aircraft to consistantly achieve wheel heights of 5 to 10 feet during heavy weight LAPES.

> 4. Rigging methods for heavy weight loads should be designed for load survival when LAPES airdropped at wheel heights up to 20 feet and/ or methods or systems should be developed to allow the aircraft to consistantly achieve wheel heights of 5 to 10 feet during heavy weight LAPES (page 30).

e. Following load exit, the increased pitch angle and resulting "heave" practically eliminated the possibility of hitting the nosegear on the ground during LAPES.

All low velocity airdrop components shown in the rigging diagram (see Figure C23), excluding the extraction parachutes, were satisfactory with extraction forces of up to 86,290 pounds (i.e. two 43.5R extraction parachutes). All LAPES components shown in the rigging diagram (see Figure C29) were satisfactory with extraction forces of up to 69,835 pounds.

The Army clevis was padded to preclude damage during the entire test program. No damage was sustained by the aircraft ramp or the extraction system due to contact with the padded Army clevis on any test.

> 5. The Army clevis should be padded to minimize possible damage to the ramp or the extraction system (page 30).

No difference in forces was noted on tests of parachutes with 10-foot-long adapters as opposed to 24-foot-long adapters. On one of two tests using 10-foot-long adapters, one of the 35R parachutes opened slower than when using 24-foot-long adapters. However, it should be noted that uneven opening of clusters of parachutes is not uncommon.

Deployment forces obtained ranged between 41.7% and 56.3% of the peak extraction forces.

All rope extraction lines were satisfactory. The extraction ropes were stretched by hand when measured and the circumference varied from 8.25 to 10 inches in lieu of the specified rope circumference of 7.5 inches (see Table D1).

> 6. Precautions have to be taken when selecting an extraction rope to ensure against inadvertant selection of a wrong circumference rope (page 31).

PREFACE

Testing was requested by Airdrop Engineering Division, Aero-Mechanical Engineering Laboratory (STRNC-UAP), U.S. Army Natick Research and Development Center (USANC), Natick Massachusetts. Testing was authorized by Air Force Flight Test Center (AFFTC) Program Introduction Document No. P81-08-03. This program was documented as Job Order Number 921C60. All tests were conducted by the 6520 Test Group, Aerial Delivery Branch, AFFTC. Testing reported on herein began 5 Nov. 1982 and was completed 27 Jun. 1984. This technical report constitutes closing action on this program.

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INTRODUCTION

BACKGROUND

US Army Natick Research and Development Center (USANC) has begun component development of an airdrop system capable of delivering gross weight loads of up to 60,000 pounds. These components will be used in both low velocity and low altitude parachute extraction system (LAPES) methoc of airdrop. This will provide a means for air delivery of such equipment as the M551A1 AR/AAV and M2/M3 Infantry/Cavalry Fighting Vehicles. The airborne community has a desire to apply a LAPES method of extraction parachute deployment to low velocity airdrops.

USANC requested the AFFTC to conduct tests on proposed extraction parachute subsystems for use on future platform airdrop loads ranging in weight from 31,500 to 60,000 pounds.

TEST OBJECTIVE

The purpose of this test project was to determine performance characteristics of the following extraction parachutes:

a. 35-foot diameter Single Slot (35SS)
b. 43.5-foot diameter Ribbon (43.5R)
c. 40-foot diameter Ribbon (40R)
d. 35-foot diameter Ribbon (35R)

The above parachutes were tested singly and in clusters of two to evaluate their performance characteristics for extracting a load weighing 60,000 pounds.

Various other components such as extraction lines and clevises were tested and evaluated in conjunction with the testing of the extraction parachutes.

TEST ITEM DESCRIPTION

The test items consist of a line bag extraction system using the extraction parachutes listed above and the rope extraction lines listed below. All extraction lines were 7.5 inch circumferenceSamson Nystron double braided ropes. In this report the terms "extraction line" and "rope" will be synonymous.

1. Ropes A,B and C were approximately 60 feet long, eye to eye. The eyes were formed in each end. The lines were uncoated and equipped with nylite spools in the eyes. The average weight was 140 pounds.

2. Ropes 1,2 and 3 were similar to A,B, and C except in length. They were approximately 150 feet long. The average weight was 325 pounds.

3. Rope 4 was 146 feet long eye to eye, uncoated and the ends were encapsulated in plastic. This rope had an added outer braid of polyester. Its weight was 380 pounds.

4. Rope 5 was 140 feet long eye to eye, polyurethane coated, and had composite polyurethane end spools and plastic end caps over the eyes. Its weight was 305 pounds.

5. Rope 6 was 140 feet long eye to eye, polyurethane coated, and had encapsulated end spools. Its weight was 310 pounds.

The 35SS parachute was identified by part number (PN) X68K373. The 43.5R canopy, PN 25-5864, is the canopy used as the drag parachute for B-52 aircraft. For the 43.5R canopy to be used as an extraction parachute, USANC modified it according to their drawing No. X11-1-3030. The 40R (drawing No. not available) and the 35R (USANC drawing No. X11-1-3208) were versions of the 43.5R modified by the customer.

The packed extraction parachute(s) were rigged on top of the extraction line bag and secured to the line bag with textile ties.

TEST AND EVALUATION

TEST CONDITIONS

A summary of test conditions is presented in Tables 1 and 1A. A chronology of tests is presented in Appendix B.

PROCEDURES

The first test was a tow test conducted using a C-141A aircraft. All subsequent tests were conducted from a C-130 aircraft.

Extraction system rigging for low velocity airdrop was identical to that for LAPES airdrop up to the point of attachment to the load.

The Army clevis was padded during the entire test program to preclude damage. After the first test the Army clevis padding was changed to a leather cover (local Drw No. 84C001) to prevent damage to the aircraft, see Figure 1. Also, after Test 4, cardboard or felt pads were taped to the floor on both sides of both intermediate conveyor frame assemblies to minimize the probability of damage to the frame assemblies by rope contact (see Figure 2). The drogue parachutes were packed in accordance with T.O. 13C5-1-102.

As requested by the USANC, the ropes were stretched by hand and the length measured from end to end and the circumference measured at three places: 1/4, 1/2, and 3/4 the distance from one end. A summary of these measurements is presented in Appendix D.

LAPES Test Procedures:

Airdrops and inflation-breakaway tests were conducted prior to LAPES tests to evaluate, and modify as required, the non-standard rigging procedures. Also, stability and control characteristics at LAPES flight conditions were simulated.

Airdrop load weights were approximately 35,000 or 42,000 pounds. The heaviest weight cleared for airdrop by Warner Robbins ALC is 42,000 pounds for C-130 aircraft. It was determined that testing the extraction system components with theseairdrop load weights would provide worthwhile results for forecasting component suitability. Traditionally, extraction ratios (maximum extraction force devided by load weight) vary from 0.8 to 1.5 for operational low velocity airdrop and from 1.5 to 3.0 for operational LAPES.

The landing gear was down during tests and the LAPES zone (LZ) (including 1 mile after the second set of panels) was cleared to permit touchdown and landing if necessary. Wind cutoff

TABLE 1

AIRCRAFT TEST CONDITIONS

TEST NO.	DATE	AIRCRAFT GROSS WEIGHT (LB)	INDICATED AIRSPEED (KNOTS)	DECK ANGLE (DEG)	LOAD WEIGHT (LB)	NUMBER OF RAIL RESTRAINT LOCKS ENGAGED	DIAL SETTING ON RIGHT SIDE RESTRAINT LOCKS	LOAD AFT EDGE AT FS
1[1]	5 Nov 82	225,000	130	2.0	NA	34	4.00	NA
2	8 Feb 83	142,800	130	6.0	34605	6	3.00	660
3	17 Feb 83	144,000	130	6.0	34850	7	3.50	703
4	8 Mar 83	137,000	130	5.0	34872	7	3.00	680
5	10 Mar 83	131,800	131	4.0	34872	7	3.00	688
6	18 May 83	135,000	130	4.0	35030	7	3.50	688
7	27 May 83	136,000	131	5.0	35097	7	3.25	663
7a	17 Jun 83	118,000	130	0	NA	14	NA	627
8	1 Jul 83	136,000	129	5.0	35305	7	4.00	683
9	9 Sep 83	135,000	129	6.0	34735	6	3.00	687
10	16 Sep 83	133,000	130	5.0	35205	7	3.50	687
11	23 Sep 83	130,000	129	5.0	35160	7	3.50	674
12	14 Oct 83	130,000	130	5.0	35189	6	3.75	682
13	21 Oct 83	140,000	130	5.0	35436	7	4.00	679
14	28 Oct 83	130,000	130	4.5	34895	7	4.00	682
15	2 Nov 83	130,000	130	5.0	35421	7	4.00	682

TABLE 1 (Concluded)

AIRCRAFT TEST CONDITIONS

TEST NO.	DATE	AIRCRAFT GROSS WEIGHT (LB)	INDICATED AIRSPEED (KNOTS)	DECK ANGLE (DEG)	LOAD WEIGHT (LB)	NUMBER OF RAIL RESTRAINT LOCKS ENGAGED	DIAL SETTING ON RIGHT SIDE RESTRAINT LOCKS	LOAD AFT EDGE AT FS
16	30 Nov 83	127,000	132	3.0	35420	7	4.00	714
17	9 Dec 83	105,000	130	1.0	12880	14	NA	NA
18	13 Jan 84	149,000	130	0	NA	14	NA	714
19	31 Jan 84	149,000[2]	130	0	NA	14	NA	682
20	7 Feb 84	145,000	130	0	34914	14	NA	682
20a	15 Feb 84	121,000	130	0	12894	14	NA	682
21	27 Feb 84	135,700	128	NA	35210	8	4.00	672
22	7 Mar 84	134,000	130	NA	35160	7	4.00	685
23	11 May 84	133,000	132	NA	42003	7	4.00	682
24	25 May 84	140,000	130	3.0	34796	7	3.50	682
25	27 Jun 84	127,000	132	4.0	34920	7	3.25	682

1) C-141A Aircraft used, all other tests used a C-130H.

2) Four tow tests of a 22-ft Dia R.S. Aircraft gross weights were 149,000, 147,700, 144,000 and 143,000 pounds respectively.

TABLE 1A

EXTRACTION SYSTEM TEST CONDITIONS

TEST NO.	DROGUE PARACHUTE DIAMETER (FT)	EXTRACTION PARACHUTE DIAMETER NO.DIA (FT) TYPE	EXTRACTION PARACHUTE ADAPTER LENGTH(S) (FT)	NOMINAL EXTRACTION LINE LENGTH (FT)	EXTRACTION LINE BAG TIES TYPE, STRENGTH (LB)	ARMY CLEVIS TIES NO.TURNS AND BREAKING STRENGTH (LB)
1	15 RS	1-35 SS	24	150	Double 80	2 ea. 550
2	15 RS	1-35 SS	24	150	Double 80	2 ea. 550
3	15 RS	1-43.5 R	30	150	Double 80	2 ea. 550
4	15 RS	1-40 R	30	150	Double 80	2 ea. 550
5	15 RS	1-40 R	30	60	Single 80	2 ea. 550
6	15 RS	1-43.5 R	30	60	Double 80	2 ea. 1000
7	15 RS	1-43.5 R	30	60	Double 80	2 ea 1000
7a	15 RS	1-43.5 R	30	60	Double 80	2 ea. 1000
8	15 RS	2-43.5 R	30	60	Double 80	2 ea. 750
9	15 RS	1-35 R	30	60	Double 80	2 ea. 1000
10	15 RS	2-35 R	24	60	Double 80	2 ea. 750
11	15 RS	2-35 R	24	60	Double 80	2 ea. 750
12	22 RS	1-35 R	24	60	Double 80	2 ea. 1500
13	22 RS	2-35 R	24	60	Double 80	2 ea. 1500
14	22 RS	2-35 R	24	60	Single 350	2 ea. 1500
15	22 RS	2-35 R	24	60	Single 350	2 ea. 1500

TABLE 1A (Concluded)

EXTRACTION SYSTEM TEST CONDITIONS

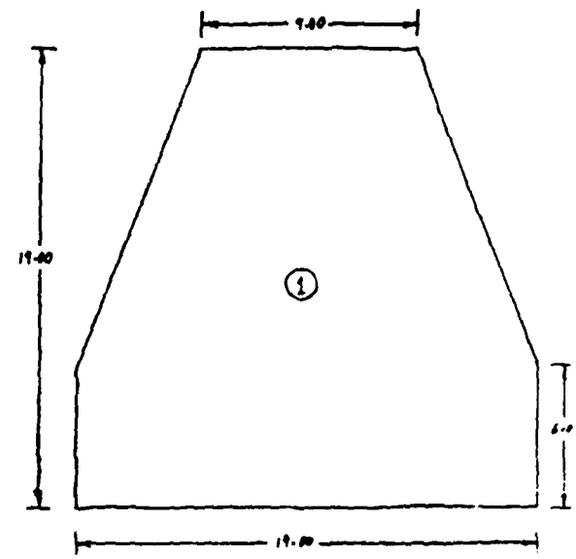
TEST NO.	DROGUE PARACHUTE DIAMETER (FT)	EXTRACTION EXTRACTION PARACHUTE NO.DIA (FT) TYPE	EXTRACTION PARACHUTE ADAPTER LENGTH(S) (FT)	NOMINAL EXTRACTION LINE LENGTH (FT)	EXTRACTION LINE BAG TIES TYPE, STRENGTH (LB)	ARMY CLEVIS TIES NO.TURNS AND BREAKING STRENGTH (LB)
16	22 RS	2-35 R	24	60	Single 575	2 ea. 1500
17	22 RS	2-35 R	24	60	Single 575	2 ea. 1500
18	15 RS	2-35 R	24	60	Single 575	2 ea. 750
19	22 RS[1]	NA	NA	NA	NA	NA
20	22 RS[2]	2-35 R	24	60	Single 575	2 ea. 1500
20a	15 RS	2-35 R	24	60	Single 575	2 ea. 750
21	15 RS	2-35 R	24	60	Single 575	2 ea 750
22	15 RS	2-35 R	24	60	Single 575	2 ea. 750
23	15 RS	2-35 R	24	60	Single 575	2 ea. 750
24	15 RS	2-35 R	10	60	Single 575	2 ea. 750
25	15 RS	2-35 R	10	60	Single 575	2 ea. 750

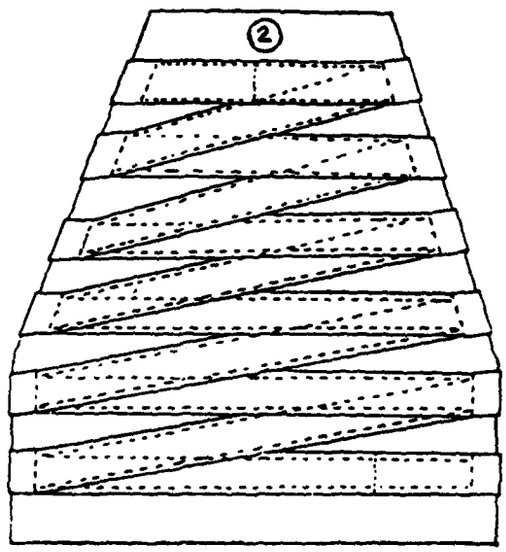
1) This test consisted of four separate tows of a 22RS reefed with 312, 354, 403, and 445 inch long reefing lines respectively.

2) One 22-ft Dia R.S. equipped with a 403 inch long reefing line.

NOTES:

1. CUT FELT AS PER SKETCH 1.
2. CUT CANVAS AND LEATHER AS PER SKETCH 3.
3. USING A BIG-ZAG PATTERN, TACK TYPE VIII COTTON WEBBING TO THE LEATHER TO FORM SIX ONE INCH LOOPS ON EACH SIDE (USE FF TO TACK) USE 6 CORD IN A STRAIGHT STITCH PATTERN OF 6 TO 8 STITCHES PER INCH TO SEW THE TYPE VIII TO THE LEATHER (SEE SKETCH 2).
4. PLACE THE FELT BETWEEN THE CANVAS AND LEATHER. (WITH THE TYPE VIII TO THE OUTSIDE)(TACK FELT WITH FABRIC ADHESIVE TO LEATHER)
5. USING A 6 TO 8 STITCH PER INCH STRAIGT STITCH PATTERN OF 6 CORD SEW THE CANVAS AND LEATHER TOGETHER. BE SURE TO GO OVER THE TYPE VIII TO FINISH THE LOOPS.





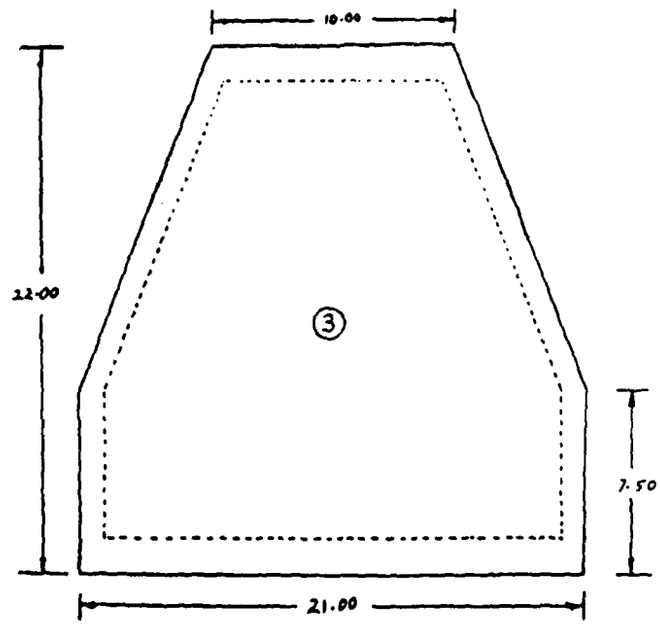


Figure 1
Army Clevis Cover

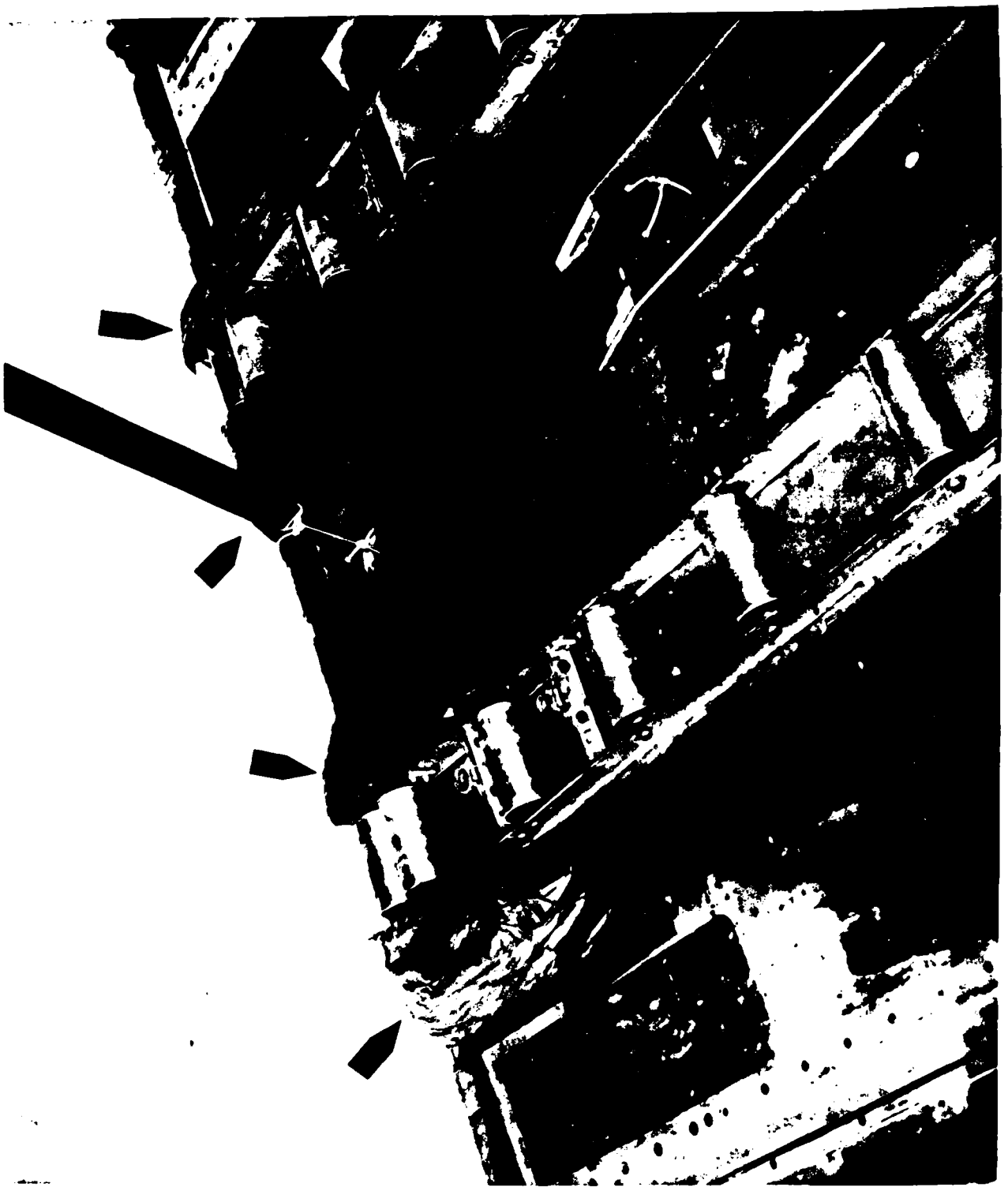


Figure 2
Cardboard Anti-Line-Snag Pads

was 35 knots direct crosswind.

A V-bridle clevis tie of three turns of Mil-W-4088 Type XVIII (6,000 pounds) was used on the last inflation-breakaway and all LAPES airdrop tests. The attitude control bar (ACB) was restrained in place using eight dacron 15,000 pound straps with 10,000 pound capacity load binders. In addition to standard ACB restraint, eight straps were added. Six of the straps provided aft restraint and two provided forward restraint (see Figures 3 and 4).

At twenty seconds out the drogue parachute was released. At this time the aircraft was at 200 feet AGL and approximately three seconds prior to reaching the descent point (3,000 feet from the release panels on the LZ). An aim-point 150-200 feet beyond the release panels was used to attain wheel heights of 20 to 30 feet over the release panels and provide wheel heights of 5 to 10 feet at load exit.

NOTE: On a standard LAPES zone, release panels are placed at a point at which the drogue parachute should be released. Impact panels are placed 500 feet down range from the release panels. The approximate point of load impact should be near the impact panels.

At T=0 (at the release panels) a tow link was released and the extraction parachutes deployed and extracted the load.

Deployment of the extraction system, weighing over 500 pounds, from the ramp (FS 750) caused a 0.75% MAC forward CG shift of the aircraft. Relatively high load restraint lock settings provided a very positive airframe "tug" as the deployed extraction parachutes reached line stretch (i.e. at snatch force). At the first indication of extraction parachute deployment, maximum power was applied. Timing was such that first movement of the load occurred about one second after the pilot leveled off near ground level.

LOW VELOCITY AIRDROP TEST PROCEDURES:

A guillotine force transfer device and a go/no-go safety device were used on all low velocity airdrop tests.

Attwenty seconds out the drogue parachute wasdeployed. At T=0 the tow link was released and the drogue parachute deployed the extraction parachutes. As the load exited the aircraft a force transfer occurred which transferred the extraction force to the recovery parachutes for deployment. The recovery parachutes (8 G-11As) then recovered the load.

RESULTS

Specific test results of forces and load speeds are

Figure 3
Attitude Control Bar Tie

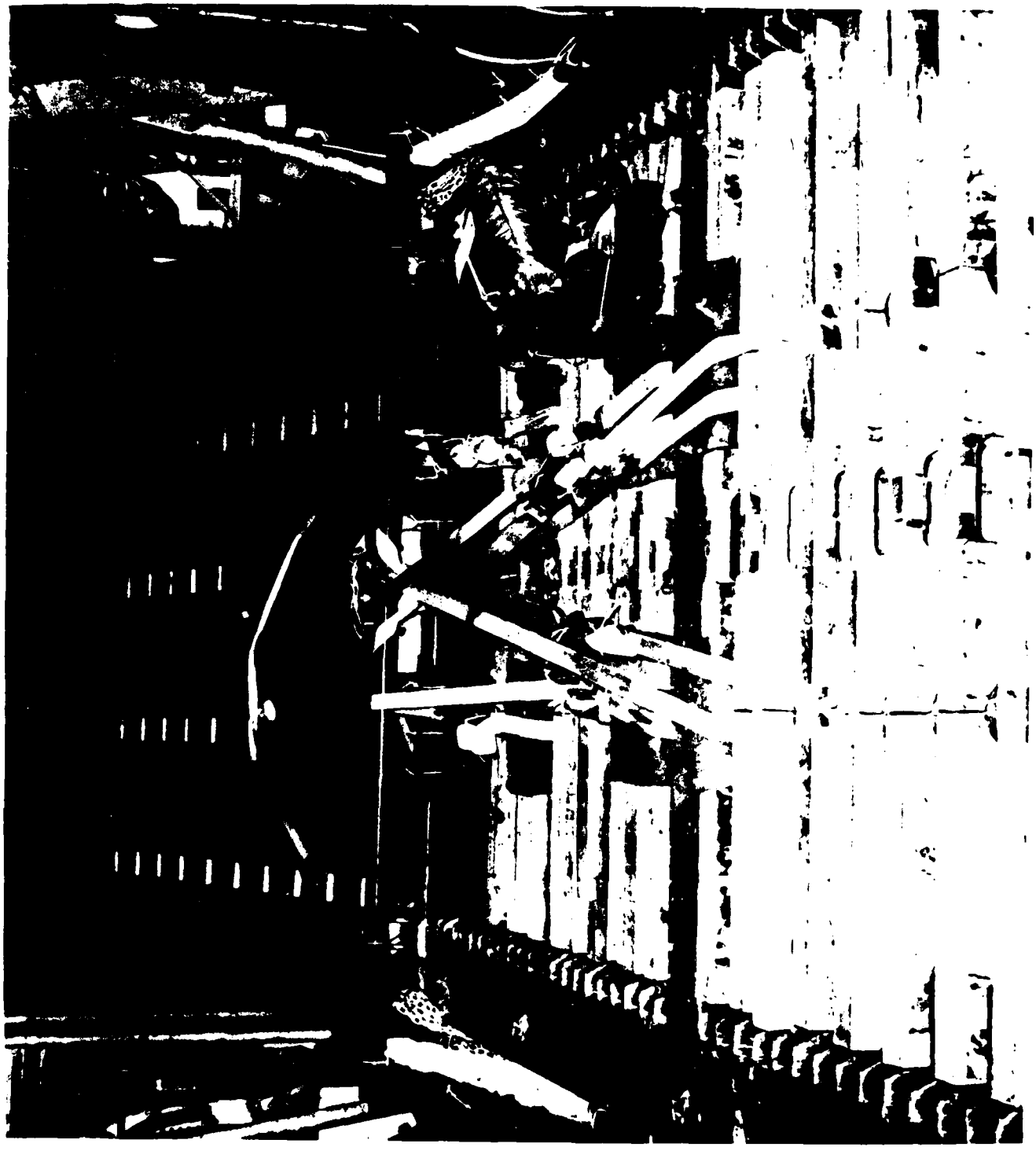


Figure 4
Attitude Control Bar Rigging

presented in Table 2.

A set of intermediate conveyor frame assemblies was damaged by the extraction line on one of four tests when no anti-line-snag pads were used (see Figure 5) and a set was damaged on one of 22 tests on which the pads were used. Anti-line-snag pads, or an alternate method should be used to minimize damage to the intermediate conveyor frame assemblies when using 7.5 inch circumference rope extraction lines. (R1)[1]

On three tests, using either an unreefed 22RS drogue or a 22RS with a 403-inch-long reefing line, the engine TIT equaled or exceeded 977 degrees C (C-130E TIT limit is 977 degrees C, C-130H TIT limit is 1083 degrees C). TIT data is presented in Table 3. The TIT was recorded on numerous dry and hot runs and therefore data in the table are not correlated to test number. With the modified HC-130H aircraft towing a 22RS or 22RS reefed 403 inches, the turbine inlet temperature (TIT) exceeded 977 degrees C during a normal LAPES profile on a relatively cool day (3 degrees C). Use of a 22RS or 22RS reefed 403 inches as a drogue parachute behind C-130E aircraft may be unsatisfactory because the C-130E TIT limit is 977 degrees C. Further testing is required prior to using a 22RS or 22RS reefed 403 inches drogue parachute with C-130E aircraft.

Low velocity airdrop tests using two 35R parachutes had an average snatch force of approximately 25,750 pounds. Reference 1 shows a snatch force of 11,000 using a C-130 aircraft flying at 140 KIAS and a cluster of three 28-Foot Do RS extraction parachutes. LAPES tests using two 35R parachutes had an average snatch force of approximately 14,050 pounds. The LAPES snatch forces were lower due to the combination of a V-bridle clevis tie and 35-foot-long V-bridle that absorbed energy during the snatch portion of parachute deployment.

The ACB rigging shown in Figure 4 was satisfactory to restrain the ACB when using a V-bridle clevis tie of three turns of 6,000 breaking strength (BS) nylon webbing (6,000 pound). The ACB should be rigged in this manner when using a V-bridle clevis tie of three turns of 6,000 pound . (R2)

On an inflation-breakaway test using an ACB V-bridle clevis tie of three turns of Mil-W-5625 (4,000 pound) tubular nylon webbing, the tie broke at line stretch. On an inflation-breakaway test using a V-bridle clevis tie of three turns of 6,000 pound, the tie did not break during snatch. During three LAPES tests the three turns of 6,000 pound nylon broke at line stretch but under such conditions that the V-bridle clevis did not contact the floor of the aircraft. Therefore a V-bridle

[1] Numerals preceded by an R within parentheses at the end of a paragraph correspond to the recommendation numbers tabulated in the Conclusions and Recommendations section of this report.

TABLE 2

TEST RESULTS

TEST NO.	MAX FORCE AT LINE STRETCH (SNATCH FORCE) (LB)	MAXIMUM EXTRACTION FORCE (LB)	MAXIMUM EXTRACTION FORCE TO LOAD WEIGHT RATIO	SPEED AT LOAD EXIT (FT/SEC)
1	NA	NA	NA	NA
2	22695	46685	1.35	50.0
3	24625	52925 [1]	NA	33.4
4	24675	50785	1.64	50.0
5	6140 [2]	32205 [3]	NA	27.8
6	20360	57265	1.63	62.5
7	22490	59890	1.71	50.0
7a	NA	NA	NA [4]	NA
8	22935	86290	2.44	72.9
9	25790	41645	1.20	45.5
10	NA[5]	57130	1.62	60.0
11	23875	56770	1.61	50.0
12[6]	30550	43835	1.25	46.9
13[7]	31295	64895	1.83	62.5

TABLE 2 (Concluded)

TEST RESULTS

TEST NO.	MAX FORCE AT LINE STRETCH (SNATCH FORCE) (LB)	MAXIMUM EXTRACTION FORCE (LB)	MAXIMUM EXTRACTION FORCE AT LOAD WEIGHT RATIO	SPEED AT LOAD EXIT (FT/SEC)
14[8]	24095	57730	1.65	56.6
15[9]	22160	67300[12]	1.90	62.5
16[10]	26135	70295[12]	1.98	75.0
17[11]	NA	NA	NA [4]	NA
18	NA	NA	NA [4]	NA
19	NA	NA	NA	NA
20	NA	NA	NA	NA
20a	NA	NA	NA	NA
21	12600	69835[12]	1.98	57.7
22	12250	55530 [12, 13]	NA	62.5
23	17340	59430[12]	1.42	54.0
24	26895	58635	1.70	55.6
25	25720	50020	1.43	57.7

1) Premature force transfer.
2) Poor extraction parachute deployment.
3) Extraction parachute damaged.
4) Inflation/Break test.
5) Data noisy - not available
6) Drogue inflated approximately 50%.
7) Drogue instrumented, force was 6,740 lbs.
8) Drogue instrumented, force was 11,540 lbs.
9) Drogue instrumented, force was 11,390 lbs.
10) Drogue instrumented, force was 8,930 lbs.
11) First test with 34 positive line bag break ties vs 17 slip breaks. System deployed horizontally. Positive line bag break ties were used for the remaining tests.
12) Drogue remained attached.
13) TM wire broke with force still increasing.

TABLE 3

ENGINE TIT DATA

GROUND OAT (°C)	GW (LB)	TIT (°C)	TORQUE (IN-LB)	DROGUE DIA (FT)	AIRSPEED (KIAS)	ENGINE BLEED AIR CONTROL VALVES	ALT AGL (FT)	FLAPS (%)
3	127000	977	NA	22	132	OPEN	2600	50
21	148000	790	8700	NA	150	OPEN	1000	50
21	148000	770	7700	NA	130	OPEN	200	70
21	148000	780	8900	NA	130	OPEN	10	70
21	144000	780	8700	NA	150	CLOSED	1000	50
21	144000	770	8500	NA	140	CLOSED	1000	70
21	144000	770	8500	NA	130	CLOSED	200	70
8	149000	820	10500	NA	150	OPEN	1000	50
8	149000	820	9300	NA	140	OPEN	1000	70
8	149000	750	8100	NA	130	OPEN	200	70
8	147000	730	8000	NA	130	OPEN	10	70
8	144000	760	8600	NA	150	CLOSED	1000	50
8	144000	790	9800	NA	140	CLOSED	1000	70
8	143000	780	10000	NA	130	CLOSED	200	70
8	149000	840	12000	22R312[1]	130	OPEN	10	70
8	147000	900	13800	22R354[2]	130	OPEN	10	70
8	144000	900	14000	22R403[3]	130	OPEN	10	70
8	143000	940	13000	22R445[4]	130	OPEN	10	70
16	147500	920	11500	22R403	128	OPEN	10	70
16	146000	980	15500	22R403	130	CLOSED	10	70
16	145000	990	16000	22R403	130	OPEN	10	70

TABLE 3 (Concluded)

ENGINE TIT DATA

GROUND OAT (°C)	GW (LB)	TIT (°C)	TORQUE (IN-LB)	DROGUE DIA (FT)	AIRSPEED (KIAS)	ENGINE BLEED AIR CONTROL VALVES	ALT AGL (FT)	FLAPS (%)
13	135700	870	11000	15	136	OPEN	10	70
6	134000	930	16000	15	132	OPEN	10	70
19	133000	900	16500	15	130	OPEN	10	70

NOTES:

1. 22RS equipped with a 312-inch-long reefing line
2. 22RS equipped with a 354-inch-long reefing line
3. 22RS equipped with a 403-inch-long reefing line
4. 22RS equipped with a 445-inch-long reefing line

NOTE: T56-A-15 Engines (C-130H) TIT limit is 1083°C

Figure 5
Damage to Roller Conveyors

clevis tie of three turns of 6,000 pound nylon was found to be satisfactory and this tie system should be used when using a LAPES extraction system with two 35R parachutes and a 7.5 inch circumference rope extraction line. (R3)

An aim-point 150-200 feet beyond the release panels consistantly yielded desired wheel heights of 5 to 10 feet at load exit.

LAPES release data are presented in Table 4. The average distance from tow link release to load impact was 827 feet. This compares to an average of 598 feet with a 31,000 pound load that was reported in Ref. 2, and 811 feet with load weights up to 50,000 pounds reported in Ref. 3. The additional distance over that for the 31,000 pound load may affect the area needed for a LAPES zone and/or the distance between the release panels and the impact panels on the LAPES zone when using an extraction system with two 35R parachutes.

No aircraft rail restraint locks were damaged on any test. No rollers were damaged due to the weight and speed of the load during extraction.

The 35SS parachute was not satisfactory for use as an extraction parachute with a 150 foot line behind C-130 or C-141 aircraft. The parachute tended to drive in a random direction rather than to deploy and remain stable behind the aircraft. Neither the 43.5R nor the 40R extraction parachutes had this tendency.

Table 4
LAPES RELEASE DATA

TEST NO.	DISTANCE FROM TOW LINK RELEASE TO LOAD IMPACT (FT)	LOAD SLIDE DISTANCE (FT)	DISTANCE EXTRACTION PARACHUTES CONTACTED GROUND DURING INFLATION (FT)
21	860	770	15
22	746	471	0
23	875	738	0

Averaged extraction force data are presented in Table 5.

The pilots reported the following:

TABLE 5

AVERAGE EXTRACTION SYSTEM FORCES
(ACTUAL AND PREDICTED)

MAJOR SYSTEM COMPONENTS	AVERAGE SNATCH FORCE (LB)	AVERAGE MAXIMUM FORCE (LB)	*PREDICTED MAXIMUM TOW FORCE (LB)
2 EA 35R, 24 ft adapters; 15RS Drogue, Unattached	25386	57512	71890
2 EA 35R, 24 ft adapters; 15RS** Drogue, Attached	14063	64633	80791
2 EA 35R, 10 ft adapters; 15RS Drogue, Unattached	26307	54327	67909
2 EA 35R, 24 ft adapters; 22RS Drogue, Unattached	27695	61313	76641
2 EA 35R, 24 ft adapters; 22RS Drogue, Attached	24147	68799	85999
2 EA 43.5R, 30 ft adapters; 15RS Drogue, Unattached	22933	86291 ***	107864 ***
1 EA 35R, 24 ft adapter; 15RS Drogue, Unattached	25789	41645	52056
1 EA 35R, 24 ft adapter; 22RS Drogue, Unattached	30552	43837	54796
1 EA 35SS, 24 ft adapter; 15RS Drogue, Unattached	22693	46689	58358

TABLE 5 (Concluded)

AVERAGE EXTRACTION SYSTEM FORCES
(ACTUAL AND PREDICTED)

MAJOR SYSTEM COMPONENTS	AVERAGE SNATCH FORCE (LB)	AVERAGE MAXIMUM FORCE (LB)	*PREDICTED MAXIMUM TOW FORCE (LB)
1 EA 40R, 30 ft adapter; 15RS Drogue, Unattached	24674	50787	63484
1 EA 43.5R, 30 ft adapter; 15RS Drogue, Unattached	21426	58576	73220

*Obtained by multiplying average maximum force by 1.25. This is the method Aeronautical Systems Division uses to predict the force of a towed parachute.
**LAPES TESTS
***One parachute did not fully open during this test or the force would probably have been higher.

a. A moderate power increase was required to maintain 130 KIAS after deploying a 15RS drogue parachute. Using a 22RS drogue parachute with the aircraft flying on a four degree downward flight path, the airspeed decreased approximately 5 to 10 knots, even with a maximum power setting. The aircraft accelerated approximately one foot per second per second once in ground effect.

b. Abruptly reversing longitudinal control inputs while the load is moving aft (specifically releasing forward yoke pressure once it has been applied) can cause pilot induced oscillations which dampen quickly after the load exits.

c. Stick forces of 110 pounds were required during the LAPES airdrop with a 42,000 pound load. The stick force was applied smoothly and quickly at load first movement, reaching the forward stop within one second.

d. An unavoidable pitch up of 2 to 4 degrees with full forward yoke occurred as the load moved aft. This resulted in an unavoidable climb of 6 to 8 feet prior to load exit and may have an adverse effect on load survivability for initial wheel heights above 4 feet. (NOTE: standard LAPES wheel height is between 5 to 10 feet at load exit.) Heavy weight load rigging methods should be designed to allow for loads to survive when LAPES airdropped at wheel heights up to 20 feet and/or methods or systems should be developed to allow the aircraft to consistantly achieve wheel heights of 5 to 10 feet during heavy weight LAPES. Rigging methods for heavy weight loads should be designed for load survival when LAPES airdropped at wheel heights up to 20 feet and/or methods or systems should be developed to allow the drop aircraft to consistantly achieve wheel heights of 5 to 10 feet during heavy weight LAPES. (R4)

e. Following load exit, the increased pitch angle and resulting "heave" practically eliminated the possibility of hitting the nosegear on the ground during LAPES.

All low velocity airdrop extraction system components shown in the rigging diagram (see Figure C23), excluding the extraction parachutes, were found satisfactory when subjected to extraction forces of up to 86,290 pounds. All extraction system components shown in the rigging diagram (see Figure C29) were found satisfactory with extraction forces of up to 69,835 pounds during LAPES airdrop tests.

No damage was sustained by the aircraft ramp or the extraction system due to contact by the padded Army clevis on any test. The Army clevis should be padded to minimize possible damage to the ramp or the extraction system. (R5)

No difference in forces was noted on tests of parachutes

with 10-foot-long adapters as opposed to 24-foot-long adapters. On one of two tests using 10-foot-long adapters, one of the 35R parachutes opened slower than when using 24-foot-long adapters. However, it should be noted that uneven opening of clusters of parachutes is not uncommon.

Deployment force (peak force transmitted to the G-11A deployment bags at force transfer) was recorded on two tests. On one test, using a 40R extraction parachute, the peak deployment force was 21,200 pounds versus a peak extraction force of 50,800 pounds (41.7%). On the other test using a cluster of two 35R extraction parachutes the peak deployment force was 33,000 pounds versus a peak extraction force of 58,600 (56.3%).

All extraction lines were structurally sound. The plastic encapsulation on line 4 sustained a 4-inch-long crack through to the rope; however, the line was useable in this condition. Circumference measurements were taken at three places on all the ropes (1/4 , 1/2 , and 3/4 the distance from one end). These measurements varied from 8.25 to 10 inches as opposed to the 7.5 inch circumference specified by the manufacturer. Precautions have to be taken when selecting an extraction rope to ensure against inadvertant selection of wrong circumference.(R6)

REFERENCES

1. Black, James M. , Development , Test and Evaluation of an Extraction Parachute Subsystem For Airdrop From the C-5A Aircraft, AFFTC-TR-69-29,Air Force Flight Test Center, Edwards AFB, California, October 1969.

2. Laine,Charles O., Development and Evaluation of a C-130 Aircraft Low Altitude Parachute Extraction System for Aerial Delivery of Single and Tandem Cargo Platforms at Ground Proximity, AFFTC-TR-68-3,Air Force Flight Test Center, Edwards AFB, California, March 1968.

3. Rutan, Elburt L. and Stroup, Floyd B., Evaluation of the C-130E Stability and Control Characteristics During Tandem, Sequential and Single-Platform LAPES Deliveries and Airdrop Deliveries,AFFTC-TR-67-18, Air Force Flight Test Center, Edwards AFB, California, November 1967.

APPENDIX A

FORCE TIME PROFILES

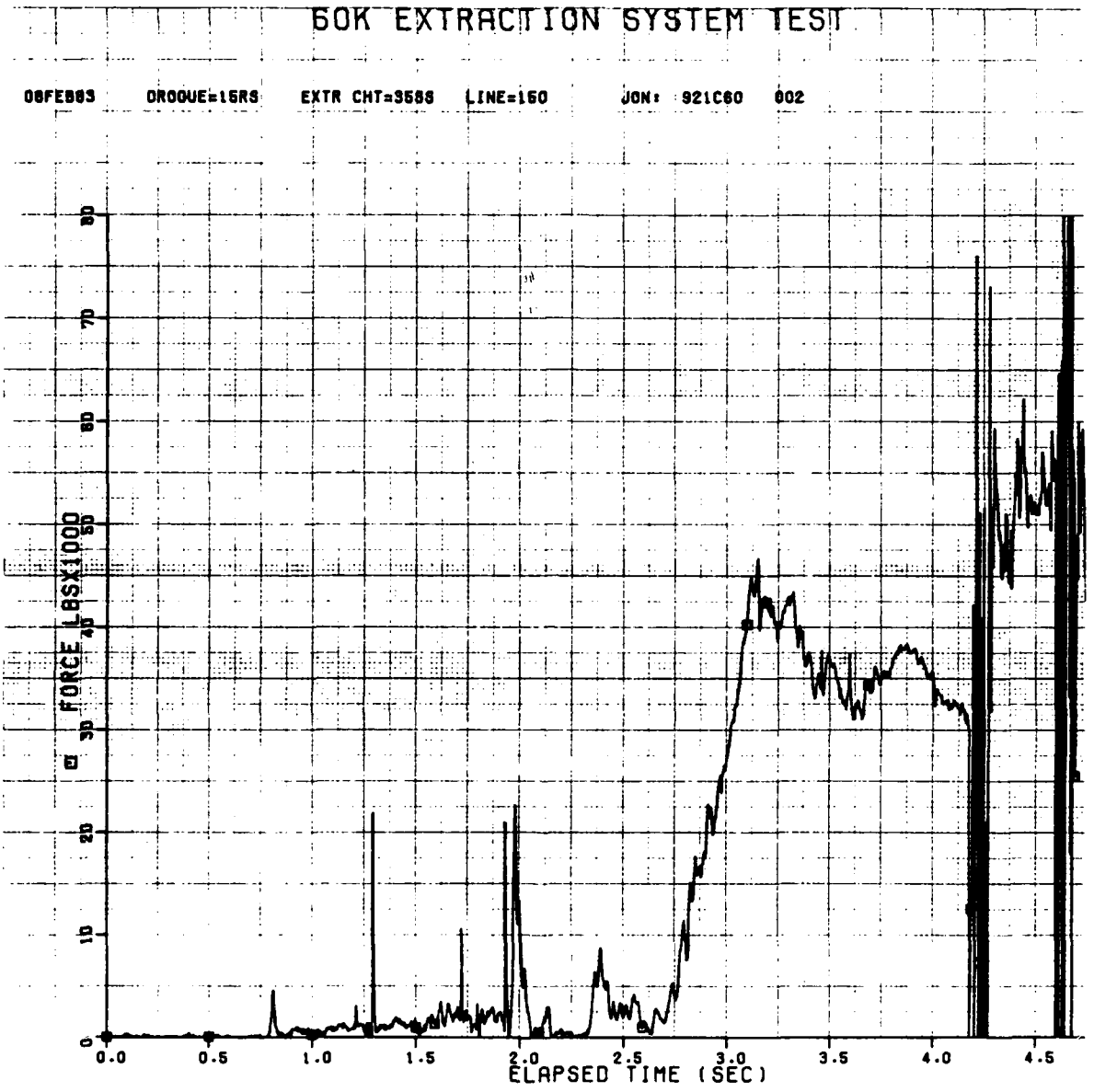


Figure A1
Force Time Profile , Test 2

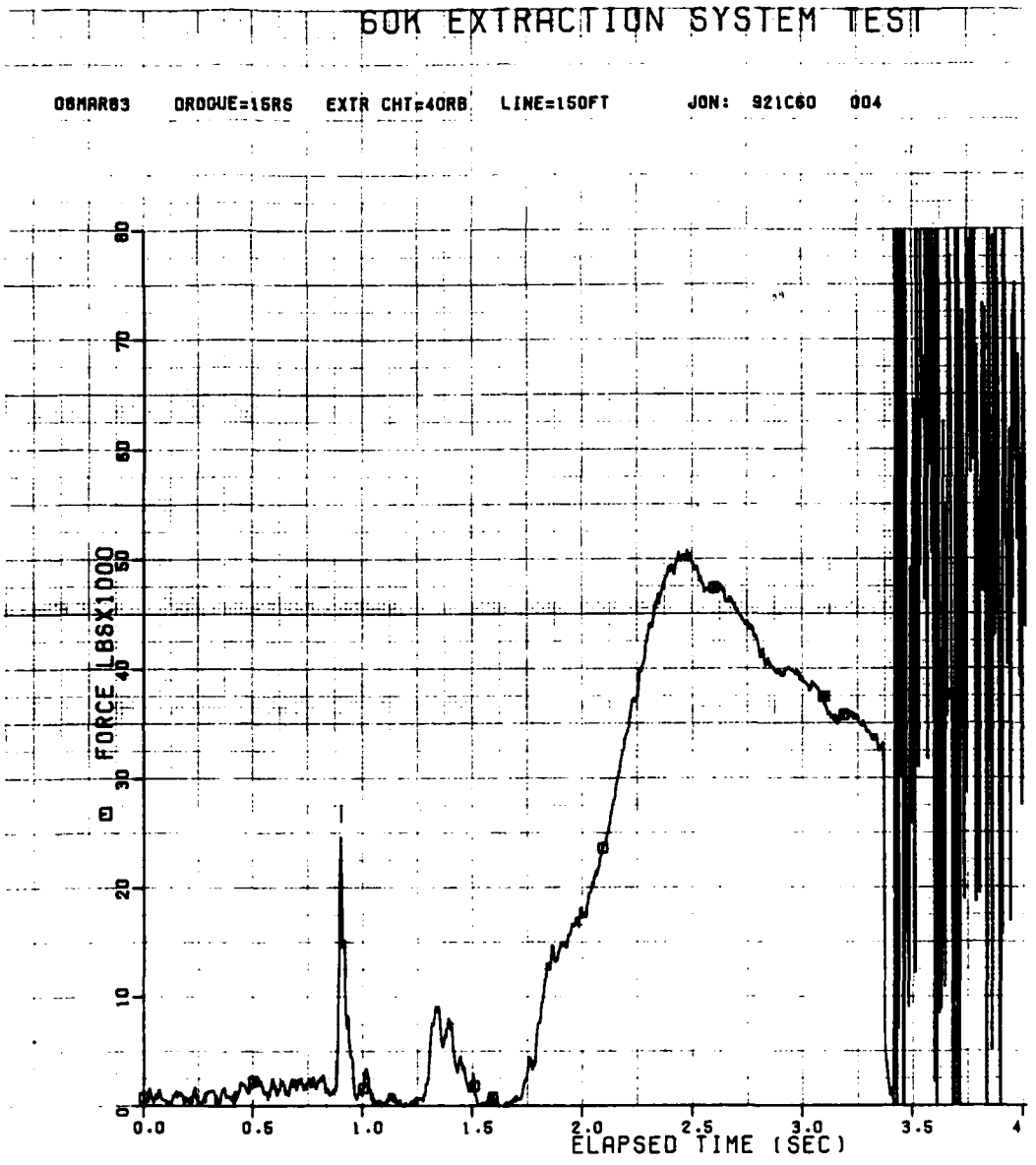


Figure A2
Force Time Profile , Test 4

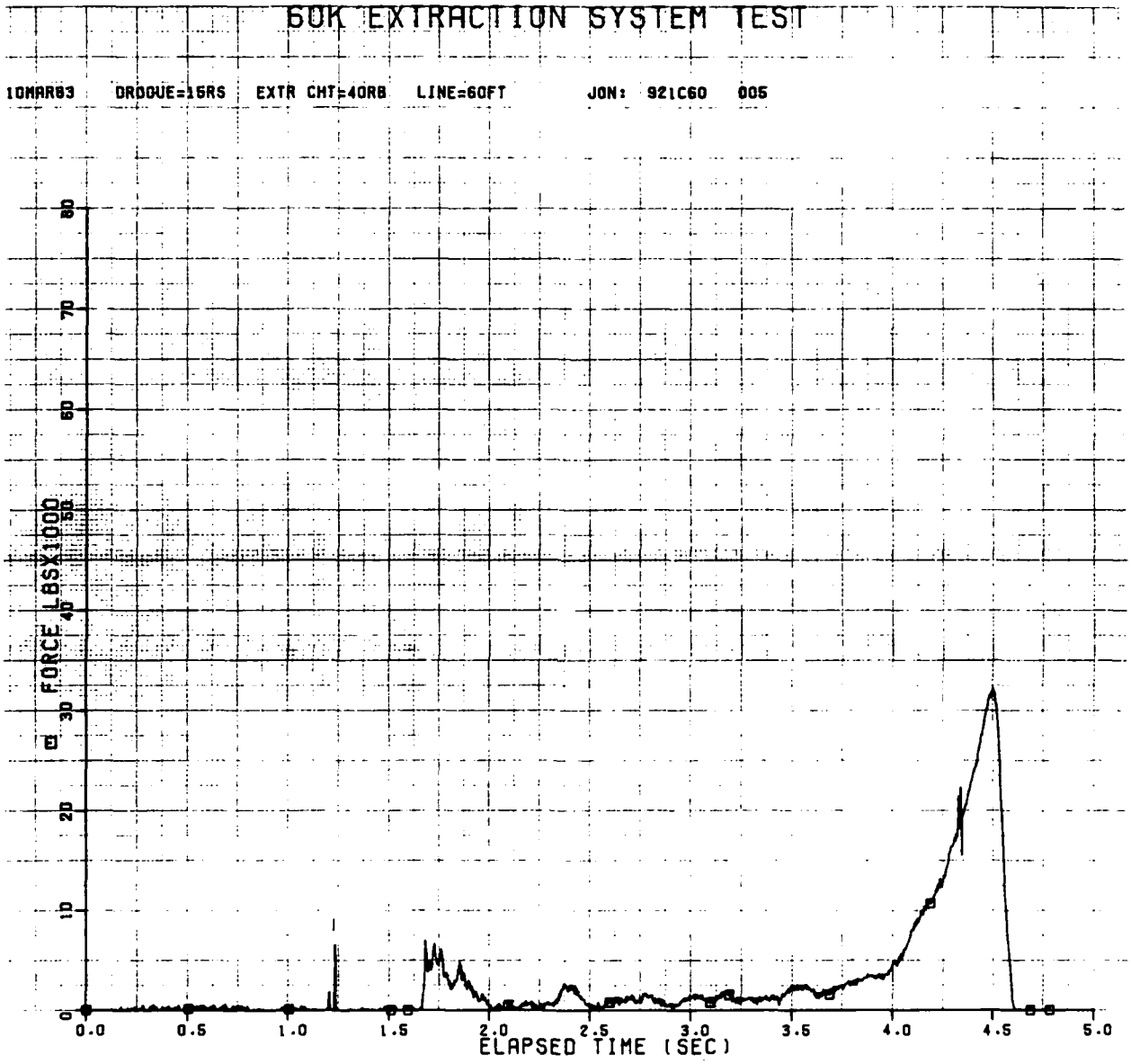


Figure A3
Force Time Profile , Test 5

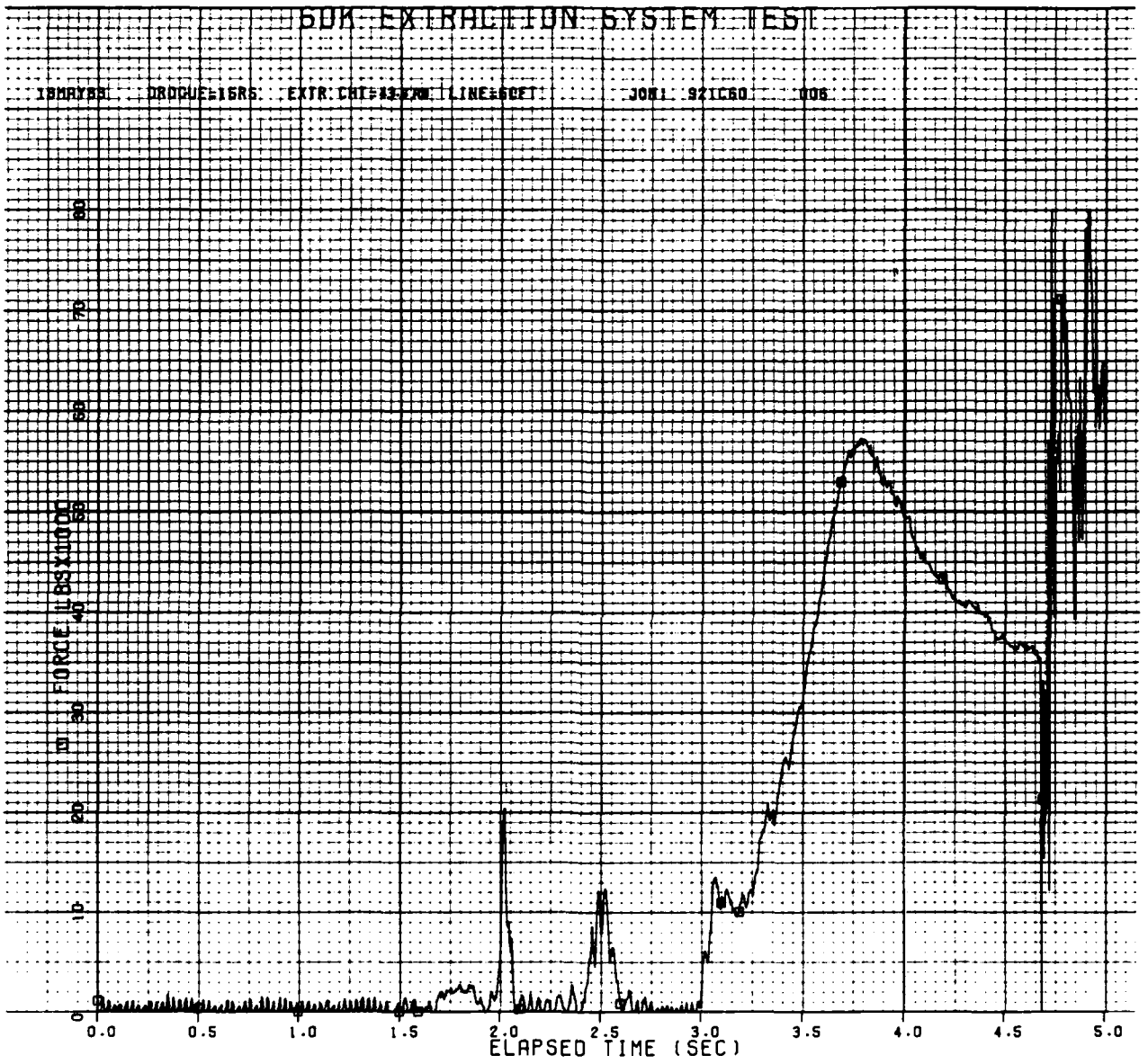


Figure A4
Force Time Profile , Test 6

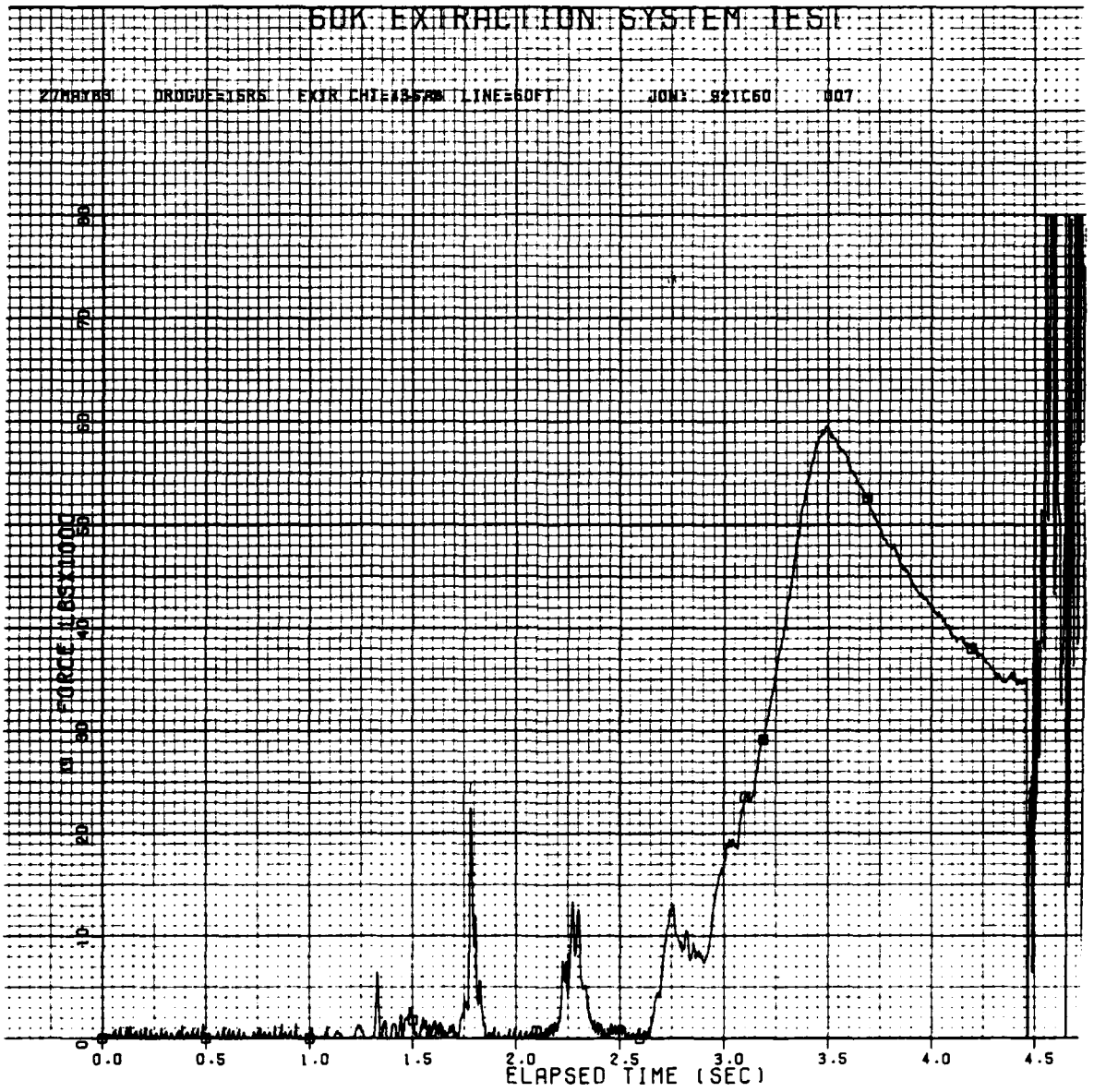


Figure A5
Force Time Profile , Test 7

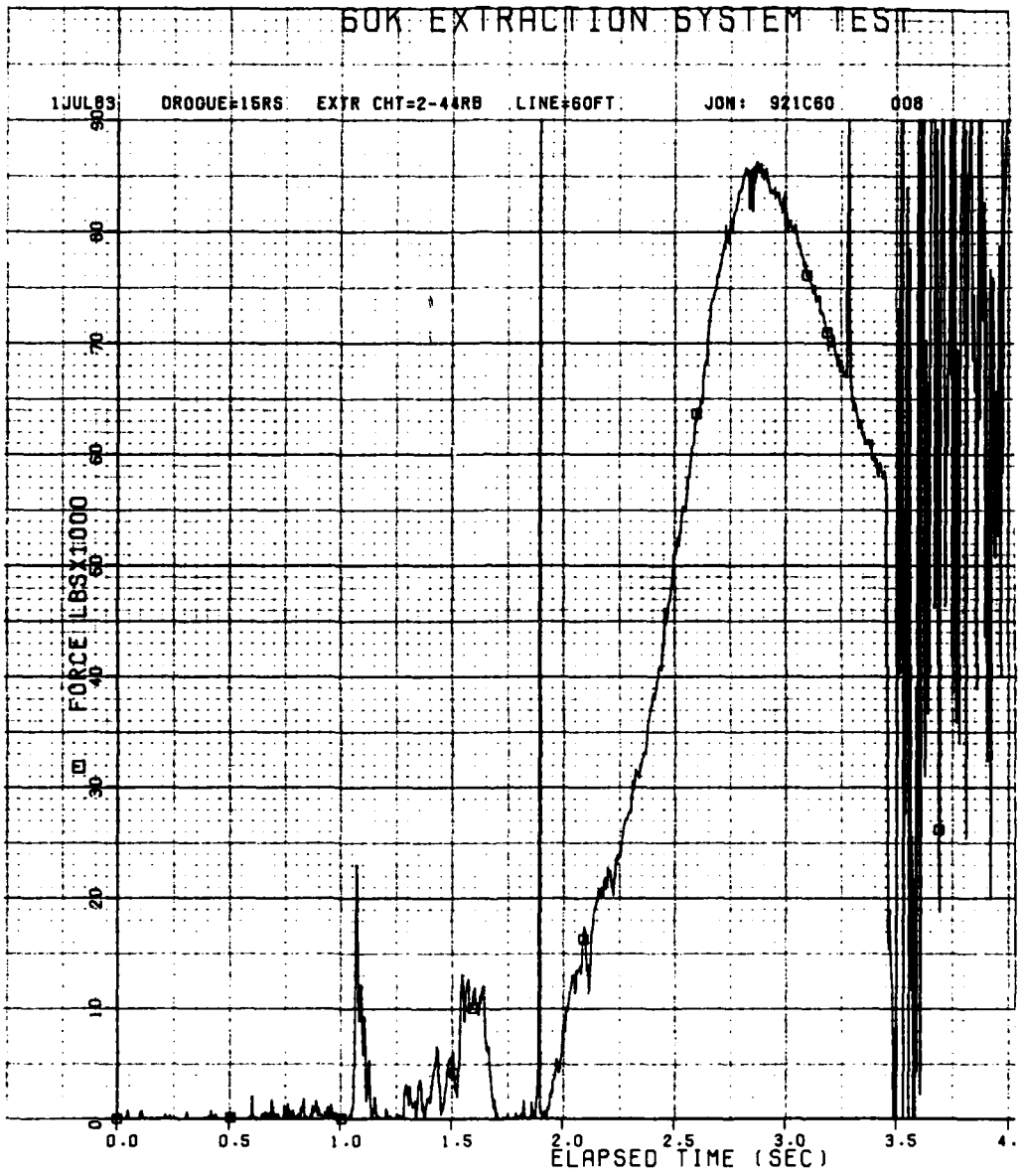


Figure A6
Force Time Profile , Test 8

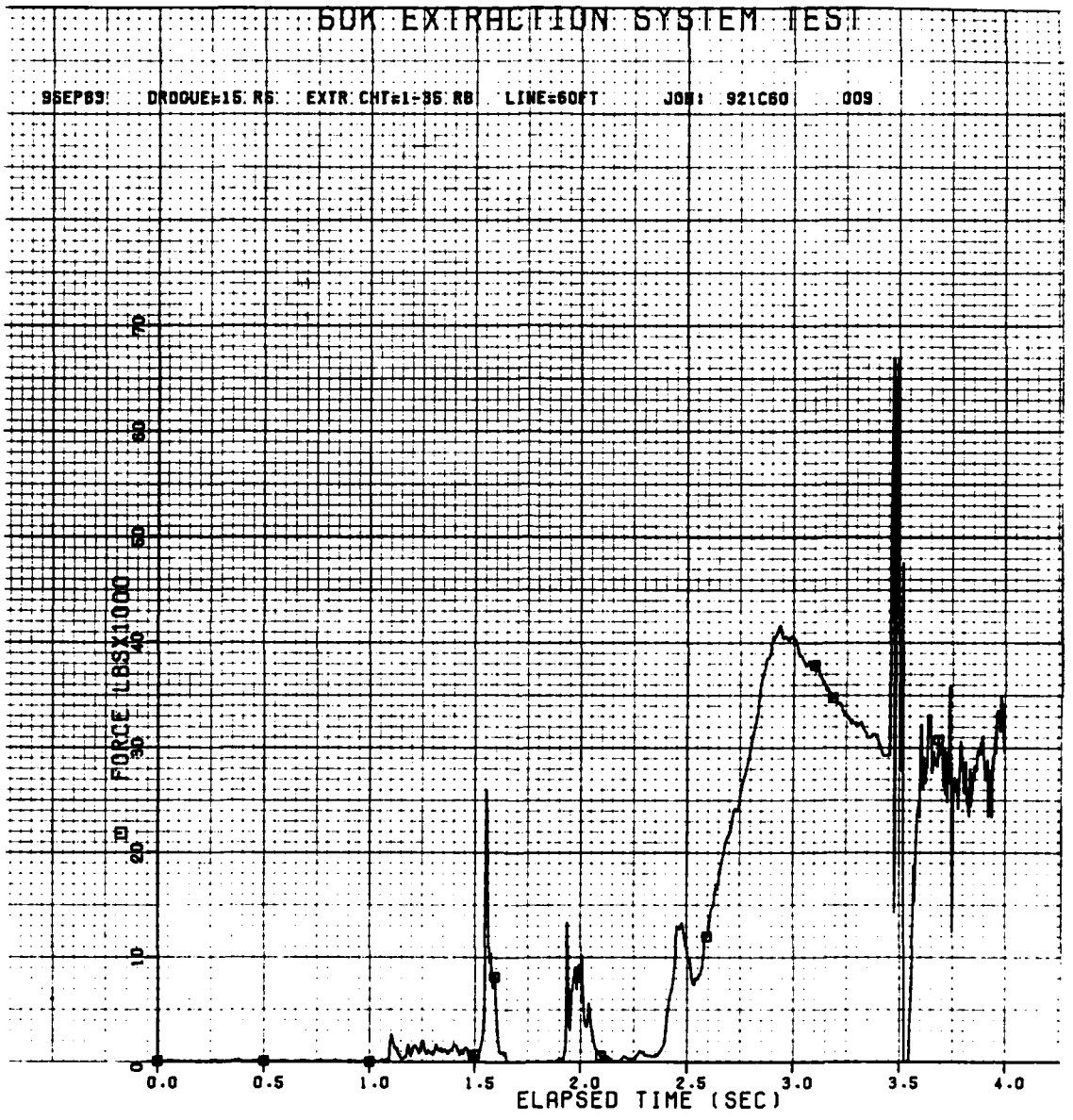


Figure A7
Force Time Profile , Test 9

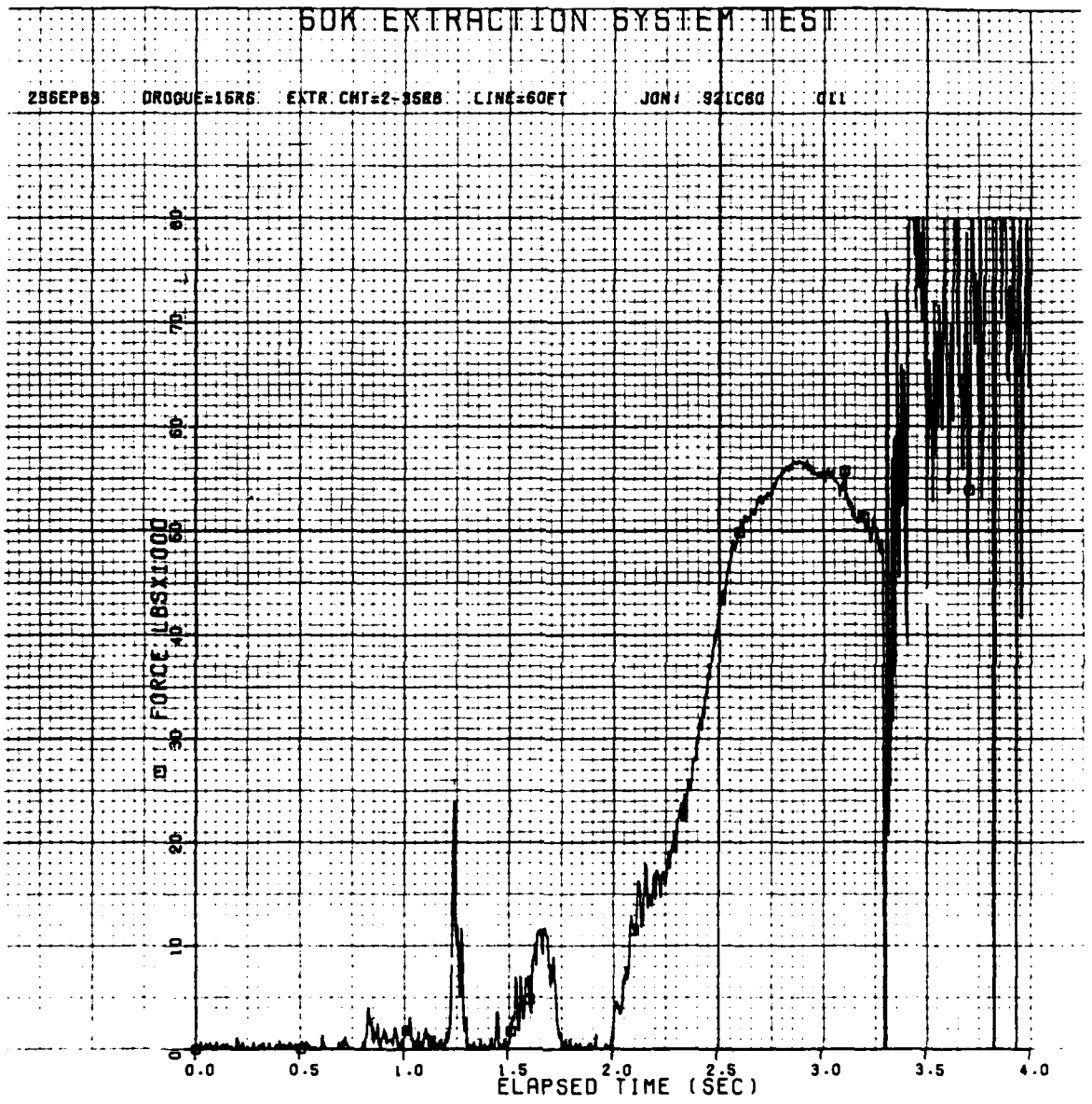


Figure A8
Force Time Profile , Test 11

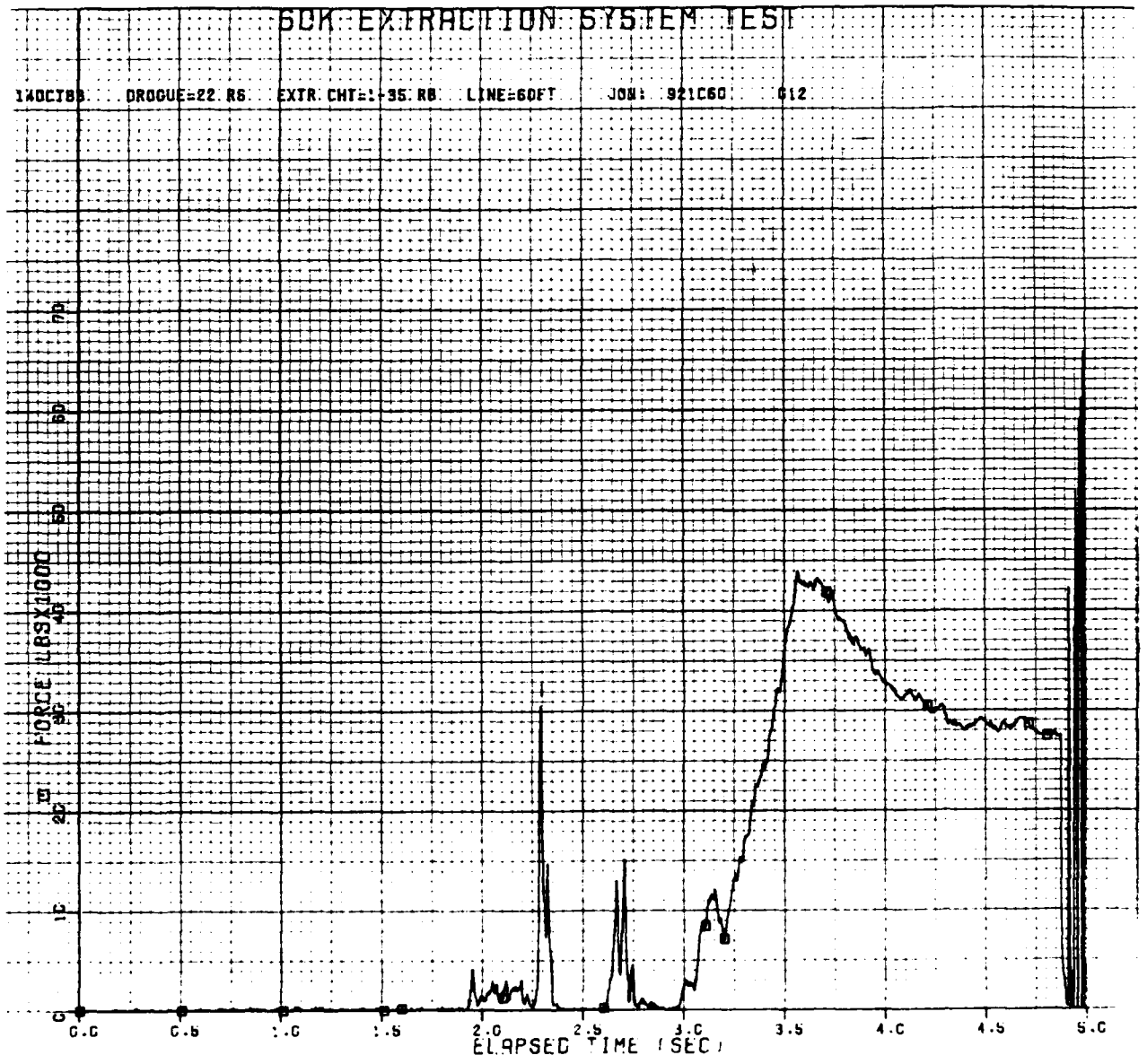


Figure A9
Force Time Profile , Test 12

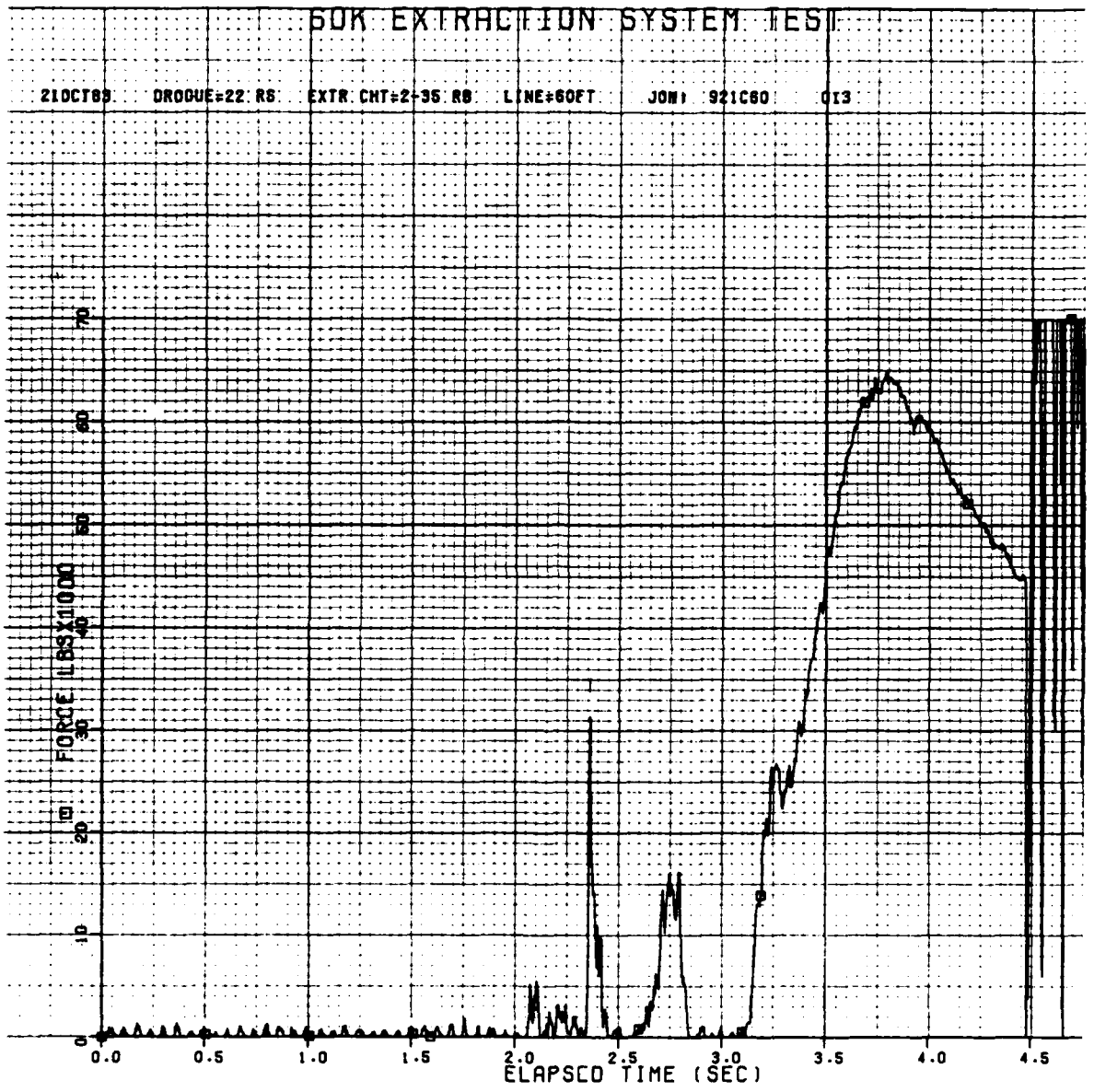


Figure A10
Force Time Profile , Test 13

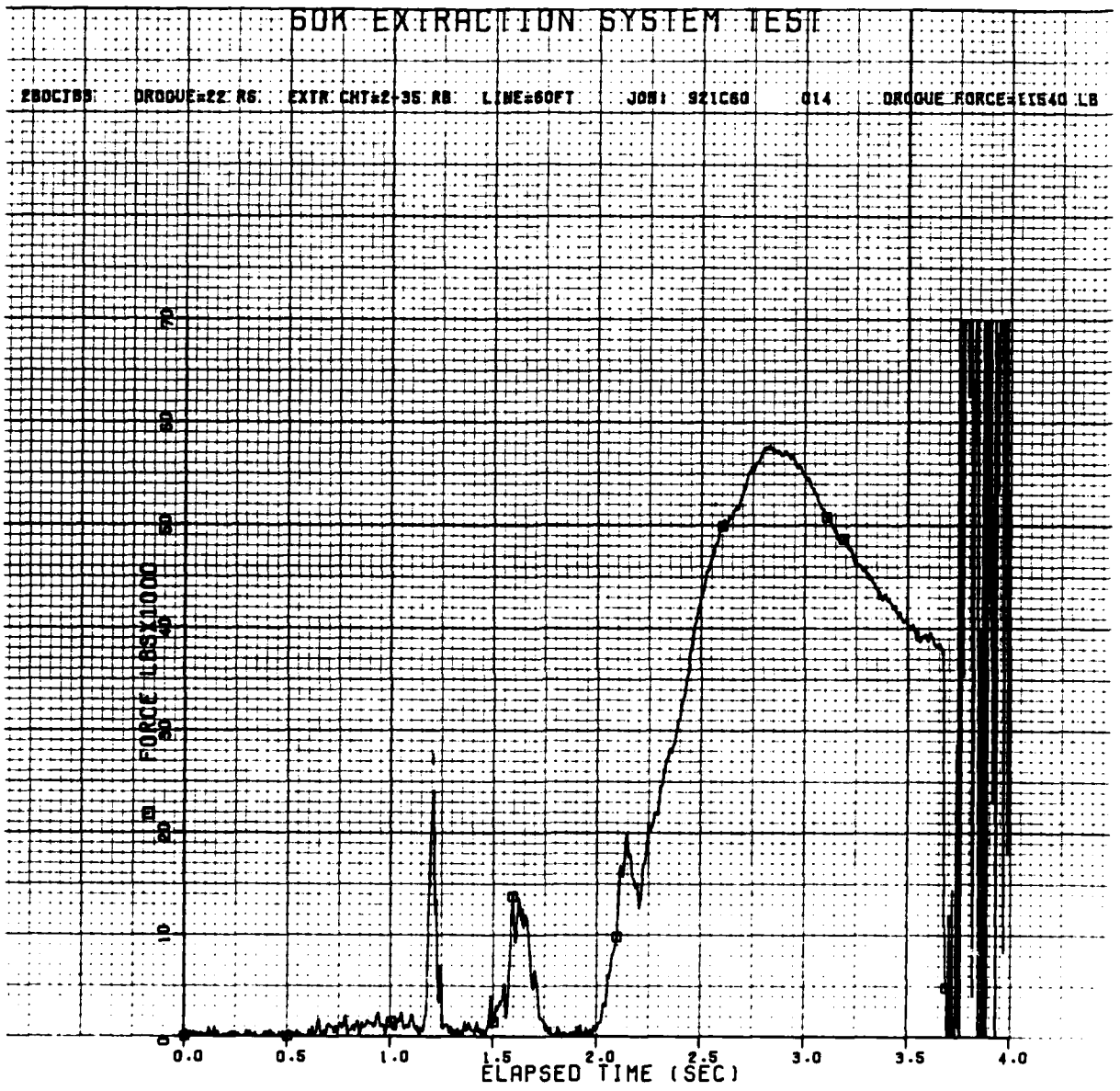


Figure A11
Force Time Profile , Test 14

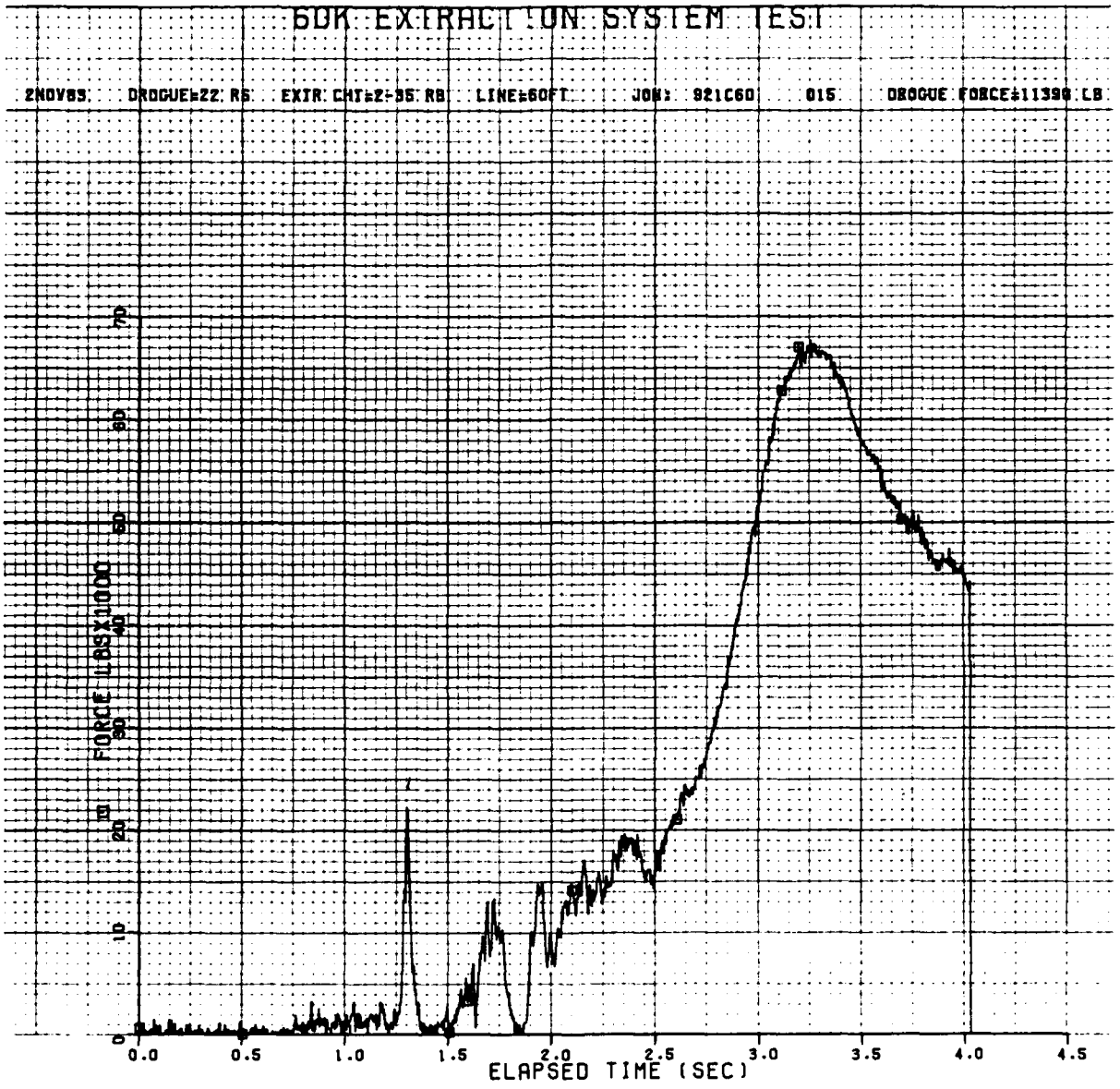


Figure A12
Force Time Profile , Test 15

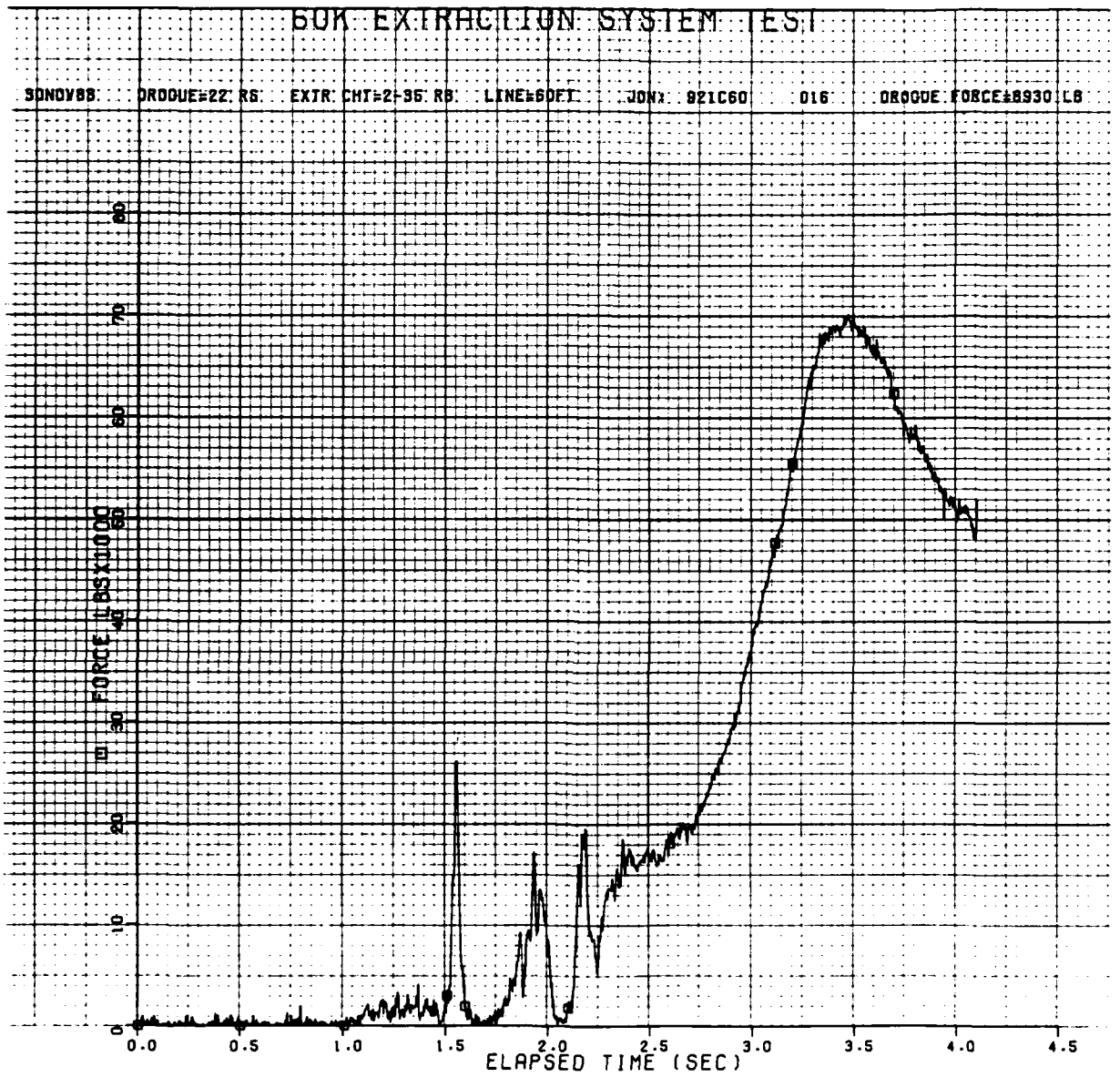


Figure A13
Force Time Profile , Test 16

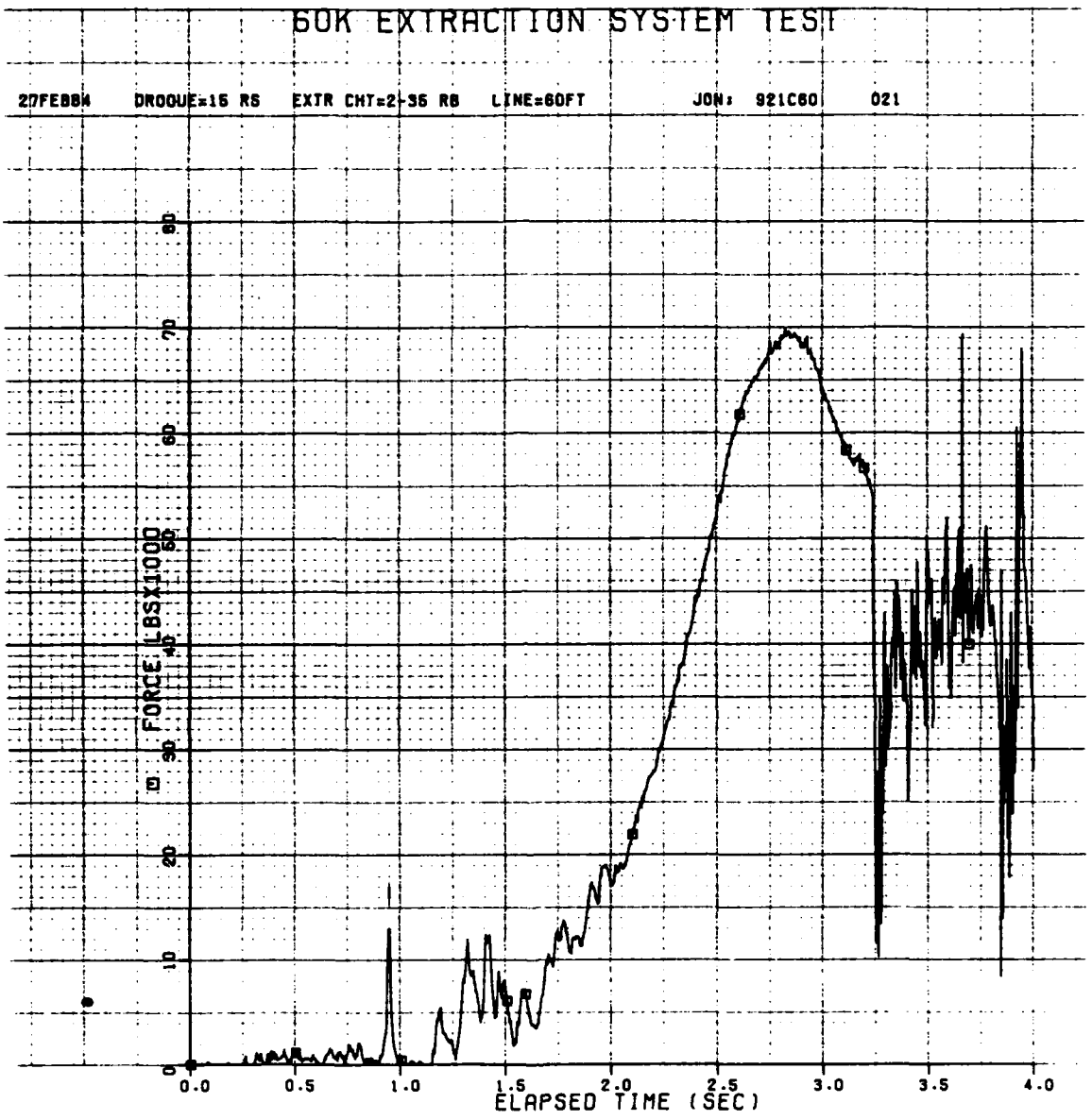


Figure A14
Force Time Profile , Test 21

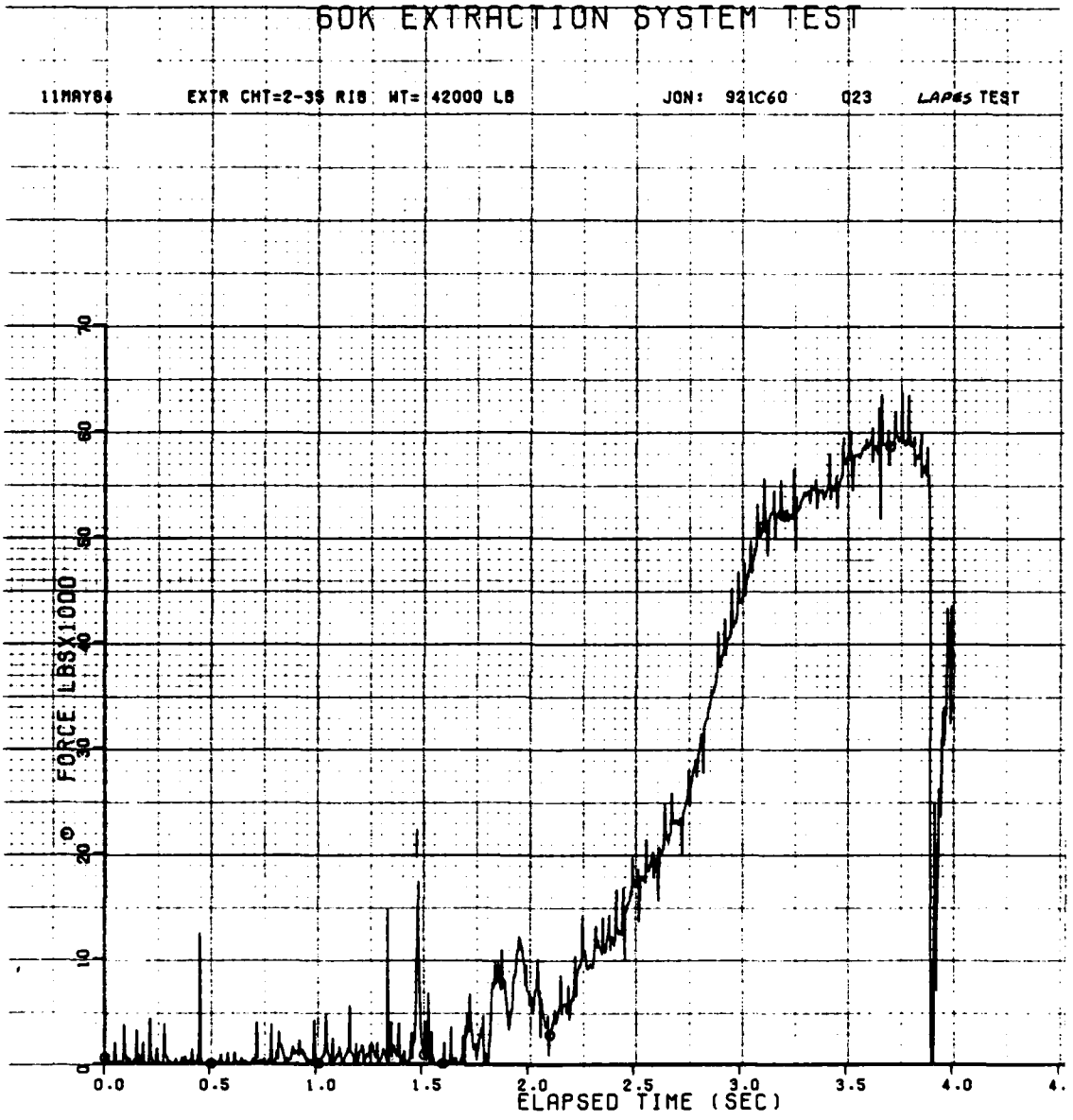


Figure A15
Force Time Profile , Test 23

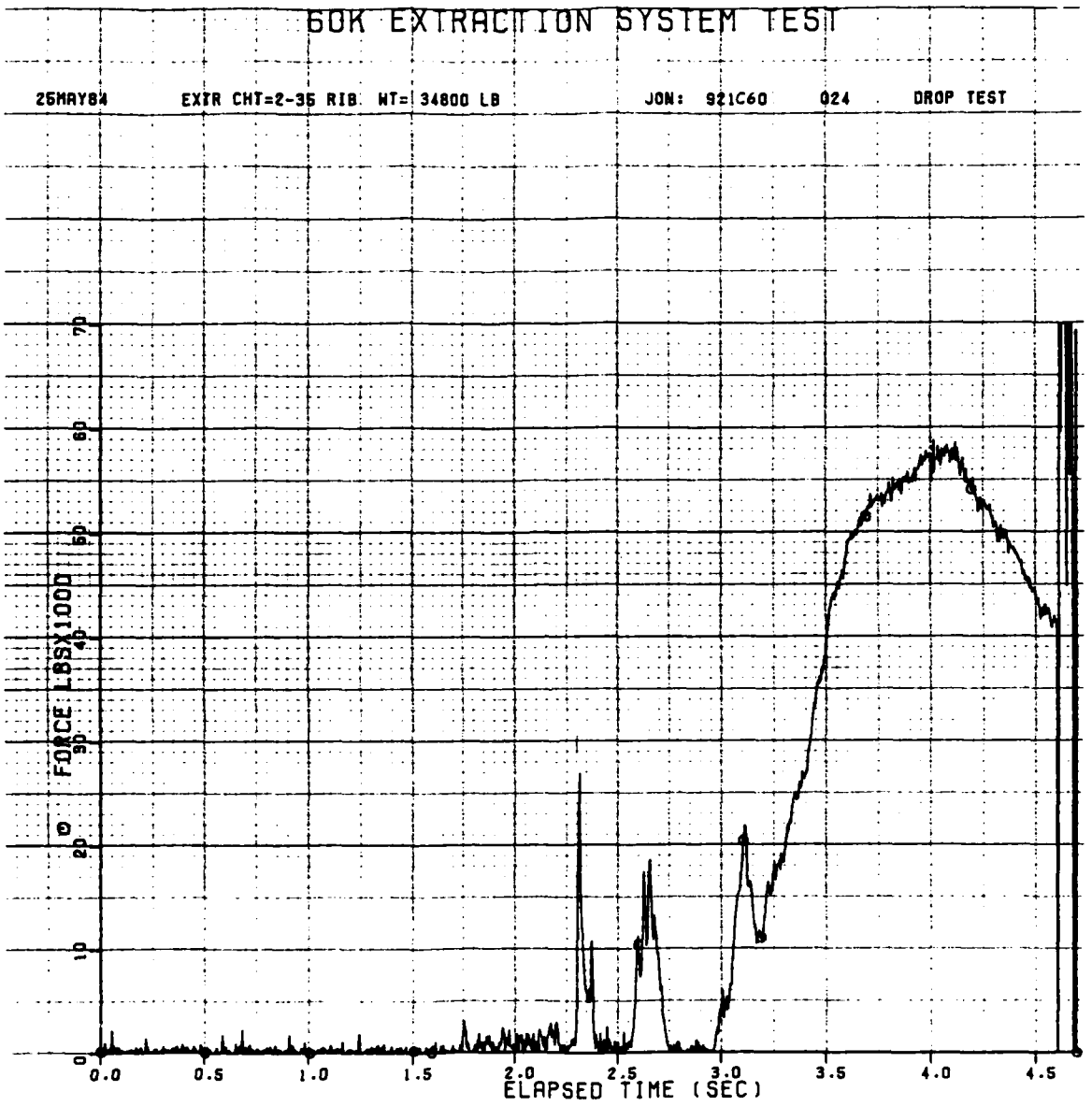


Figure A16
Force Time Profile , Test 24

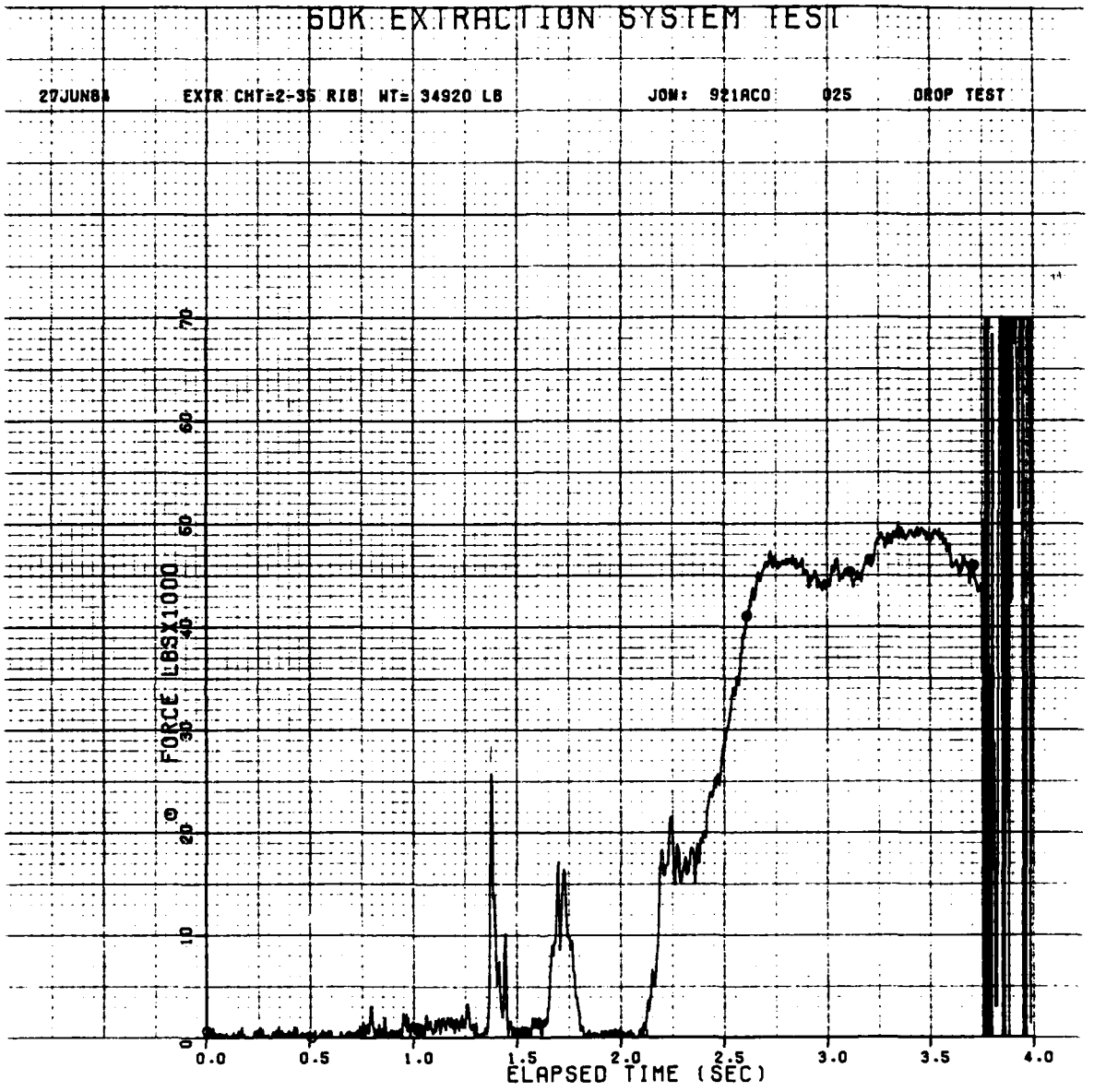


Figure A17
Force Time Profile , Test 25

APPENDIX B

NARRATIVES OF INDIVIDUAL TESTS

BACKGROUND

In order to show the system evolution,and the reasons for system changes on a test-by-test basis, it is necessary tobegin with a description of the initial system.

The major component of the system was a line-bag extraction system with one or a cluster of two of the extraction parachutes listed below:

a. 35-foot Do single slot (35SS)
b. 43.5-foot Do ribbon (43.5R)
c. 40-foot Do ribbon (40R)
d. 35-foot Do ribbon (35R)

All tests were conducted at an airspeed of approximately 130 KIAS. Airdrops and tow tests (except LAPES tow tests) were conducted at an altitude of 5,000 feet MSL. Loads weighing 35,000 or 42,000pounds, rigged on a 24-foot-long LAPES platform with skids were used on all extraction tests. The extraction lines (ropes) were made from 7.5 inch circumference braided nylon rope and were attached to the test parachutes using a clevis, provided by Natick R&D Center, referred to in this report as the Army clevis.

A typical test sequence was as follows: at 20 seconds prior to deploying the extraction system (T-20) , the drogue parachute was deployed while at 200 feet AGL and towed behind the aircraft; about three seconds after drogue deployment a descent was initiated to arrive at a wheel height of 5 to 10 feet just after the release point;at T=0 (green light), the drogue parachute (towlink) was released,deploying the extraction system; snatch force occurred at line stretch; the load released from the rail restraint locks after the extraction parachute(s) developed sufficient force and then the load was extracted from the aircraft.

TEST 1

This test was a tow test of a 35SS using a 150-foot-long extraction line and a 30-foot-long parachute adapter web (USANC drawing No. X11-1-3032). The Army clevis tie was a single turn of Mil-C-5040 Type III (550) in two places. The 35SS opened well below the ramp then drove down and to the right side. As soon as the test engineer observed this unacceptable condition he called "release chute" and the loadmaster released the towing parachute system. A clevis located in the extraction system near the tow point within the aircraft hit and damaged the C-141 ramp during exit. It was decided to halt further tow testing because this

type of damage is more likely when doing tow tests than with airdrop tests.

TEST 2

This was the first of a serie- of low velocity airdrop tests from a C-130 aircraft. The test configuration included a 35SS extraction parachute canopy equipped with a parachute adapter web 24 feet long (USANC drawing No. X11-1-3210). The adapter was equipped with a 15,000 pound capacity (15k) collar link (PN MS 24553-2), in lieu of the standard 6,000 pound capacity link (PN 52B66602), and had a cotton buffer in the collar. The extraction line bag ties were double turns of Mil-T-5661 , Type I (80 pound) cotton tape.

On this test the 35SS drove to the left as the load was extracted. As the load exited the aircraft normal force transfer occurred. The deployment line was damaged in two places, one place by a telemetry (TM) strain link clevis, and one place by a G-11A clevis bolt/nut. These two items were padded on subsequent tests to prevent similar damage.

TEST 3

The only changes on test 3 from 2 were to the extraction parachute. A 43.5R extraction parachute was equipped with a 30 foot adapter(USANC drawing No. X11-1-3032). The collar had no cotton buffer. The type of extraction parachute was changed because of the 35SS tendency to drive randomly to the side on the previous tests.

The test sequence was normal until the first 2-3 feet of load travel. At that point, the guillotine transfer device cut the cutter web prematurely and initiated force transfer. However, at this location, the go/no-go was unlocked, resulting in no force transfer to the recovery parachutes. The load exited the aircraft by gravity and was destroyed.

The rigging method was altered to preclude premature transfer.

TEST 4

The major change in this test was the substitution of the 40R extraction parachute. The 30 foot adapter had the standard 5k collar link and had no cotton buffer. All subsequent tests used 6k collar links (except on test 7) and did not use a cotton buffer on the collar.

During load extraction the extraction line contacted an intermediate conveyor frame assembly , bending it to the left and dislodging two rollers. Subsequently a portion of the conveyor frame assembly rails was cut off by platform skid contact as the

load exited.

On subsequent tests, cardboard or felt anti-line-snag pads were taped to the floor on both sides of both intermediate conveyor frame assemblies to minimize this problem (see Figure 2).

TEST 5

The major change from the last test was the use of a shorter extraction rope (approximately 60-foot-long) in order to reduce the distance the extraction system fell during deployment. The line bag stow ties required 17 slip ties of a single turn of 80 pound cotton tape to try to reduce snatch force. This length extraction rope was used on all subsequent tests.

Immediately following drogue release, the extraction line and extraction parachutes deployed poorly (i.e. they "dumped"),and subsequently during inflation the canopy separated from all of its suspension lines. This precluded the normal sequence of events. The recovery system was not deployed and the load was destroyed.

The causes of the two malfunctions were (1) the initial system acceleration at drogue release caused the Type III MIL-C-5040 nylon cord ties between the Army clevis and the extraction parachute deployment bag to break , dumping the parachute and line (malfunction 1), and (2) the modified parachute was not sufficiently strong to withstand the drag forces (malfunction 2).

The following corrective actions were taken on later tests when applicable:

a. The Army clevis was attached to the deployment bag to preclude snagging on the floor.

b. The ties attaching the Army clevis to the parachute bag(s) were made stronger, and the clevis was relocated nearer to the top of the parachute deployment bags.

c. The modification to the test parachutes was changed so that suspension line attachment was at least as strong as on the basic 43.5R parachute prior to modification.

TEST 6

The test condition change was to use a 43.5R parachute . The line bag stow ties were increased to double turns of 80 pound cotton tape.

The drogue-deployed 43.5R parachute inflated and extracted the load. The recovery system functioned normally.

TEST 7

The configuration was the same as 6 except that a 15k collar link was inadvertantly used in lieu of a 6K collar link.The load was extracted and recovered. .This test verified the repeatability of the extraction forces obtained in test 6.

TEST 7A

This was a LAPES inflation-breakaway test using a 43.5R extraction parachute.The line bag stow ties were reduced to one turn of 80 pound cotton tape. The Army clevis ties were one turn of MIL-W-5625 tubular nylon webbing (1,000 pound) in two places. This test was conducted to determine the suitability of this extraction system in a LAPES environment.

The flight profile was a comparatively long approach to the release panels while flying at an altitude of 5-10 feet AGL. The extraction line bag hit the ground during deployment. The parachute and bag were dragged approximately 150 feet on the ground while deploying. The parachute started to inflate then broke away normally. Wheel height at the release panels was estimated to be 4 to 7 feet.

TEST 8

This was another low velocity airdrop. A cluster of two 43.5Rs were used as extraction parachutes and the extraction line length was 68 feet. Line bag ties were one turn of Type III MIL-C-7515 (750 pound) nylon braided cord in two places. This test was conducted to ascertain the forces developed for potential LAPES airdrop use with up to 60,000 pound loads.

Data analysis showed that the drogue parachute dropped approximately 12 feet below the ramp while deploying. The extraction parachutes dropped approximately 28 feet below the ramp before inflation, and the bottom of the skirt was 37 feet below the ramp after inflation. This would not be compatible with existing LAPES airdrop procedures.

Inspection revealed one of the 43.5R parachutes had broken ribbons near the apex area and broken stitches on the lower end of 22 suspension lines. One of the parachute deployment bags had some burns on its closure flaps.

TEST 9

The test was with a single 35R extraction parachute with the intent of producing a parachute suitable for extracting 60,000 pound loads when used in a cluster of two. The parachute adapter was 24 feet. The line bag stow ties were double turns of 80 pound cotton tape. The Army clevis ties were one turn of 1,000

pound tubular nylon webbing in two places. There was no damage.

TESTS 10 AND 11

Both test configurations were an airdrop with a 15RS drogue parachute and two 35R extraction parachutes. The line bag stow ties were a double turn of 80 pound cotton tape. The Army clevis ties were a turn of 750 pound nylon cord in two places. There was no damage.

TEST 12

The test used a 22RS drogue, and a single 35R extraction parachute. A 22RS drogue was used in an attempt to deploy the extraction system more horizontally in relation to the ramp, thereby improve on the results of test 8. The Army clevis ties were one turn of 1,500 pound BS tubular nylon webbing (1,500 pound) in two places.

NOTE: The 22RS was towed from the ramp using an in-house-designed textile attachment required because the standard tow plate was designed only for a 15RS and was not cleared for the forces developed by a 22RS.

All subsystems operated normally. There was no damage. It appeared that the use of a 22RS drogue improved extraction system deployment.

TEST 13

The only test configuration change was the use of a cluster of two 35R extraction parachutes. The extraction and recovery sequences were normal. There was no damage.

TEST 14

The only change from the previous test configuration was that the line bag stow ties were a single turn of type I MIL-W-5665 (350 pound) cotton webbing.

At approximately T-5 seconds the 22RS drogue was deployed. After inflation the drogue did not break a weak link on the tow system which would have initiated extraction parachute deployment. The loadmaster then initiated the extraction sequence by using a back-up knife in the tow system. All subsystems operated normally. There was no damage.

TEST 15

The only change was the permanent attachment of the 22RS drogue to the extraction parachute system by two 98-foot-long drogue lines (rigged in parallel). Again, the change was made to try to get the extraction system to deploy higher.

All subsystems operated normally. There was no damage.

TEST 16

The only change from the previous test was that the line bag stow ties were one turn of Type II MIL-W-5665 (575 pound) cotton webbing. The change was made to try to reduce the snatch force and to deploy the extraction system higher.

All subsystems operated normally. There was no damage. However, concern was growing in regard to aircraft engine capabilities and this was the first test on which engine turbine inlet temperature (TIT) was recorded. While towing the 22RS, the TIT reached 977 degrees C. (This was on an HC-130H and the maximum allowed TIT on a C-130E, normally used by MAC, is 977 degrees C; C-130H TIT limit is 1083 degrees C).

TEST 17

This test was the first LAPES inflation-breakaway which used 34 positive line bag stow ties versus 17 slip breaks.

This system did not contact the ground during deployment and the following partial inflation and breakaway from the aircraft were as planned. Wheel height was 11 feet at the first set of panels. Positive ties were used on all subsequent tests.

TEST 18

This again was a LAPES inflation-breakaway of two 35R extraction parachutes. Since the TIT limit might preclude the use of a 22RS drogue, a 15RS drogue parachute was used to determine if this drogue would provide acceptable extraction system deployment. The Army clevis ties were one turn of 750 pound nylon cord in two places.

During the extraction parachute deployment the parachutes contacted the ground and skidded for approximately 90 feet and then started to open when the planned breakaway occurred.

TEST 19

This was four separate tows of a 22RS drogue, each with different reefing. The reefing line lengths were 312,354,403, and 445 inches. The purpose was to determine the maximum tow force compatible with C-130E aircraft TIT limits. The outside air temperature(OAT) was recorded as eight degrees C. The tow force was not obtained on the test with a 312 inch reefing due to a telemetry system malfunction. The forces obtained with the remaining parachutes were 7850, 9550, and 10950 pounds and the TIT's were 840, 900, 900, and 940 degrees C respectively.

TEST 20

This was a LAPES inflation-breakaway test using a 22RS drogue parachute reefed to 403 inches, and a cluster of two 35R extraction parachutes. The line bag stow ties were changed from test 18 to one turn of 575 pound cotton webbing. The Army clevis ties were one turn of 1,500 pound tubular nylon webbing in two places.The extraction line tied to the ACB with three turns of MIL-W-5625 (4,000 pound) tubular nylon webbing. This simulated a V-bridle hardware tie to the ACB. The intent was to hold through snatch force onset and ultimately prevent hardware from contacting or damaging the ramp; however, the tie broke at snatch force onset.

TEST 20A

This was a LAPES inflation-breakaway test with a steeper LAPES flight descent profile. The profile was used in an attempt to find a suitable LAPES system which could use the standard tow plate. The test configuration differed from the previous tests in that the drogue parachute was a 15RS, the clevis ties were one turn of 750 pound nylon cord in two places and the V-bridle clevis tie to the ACB was three turns of MIL-W-4088 type XVIII (6,000 pound) nylon webbing.

The drogue system operated normally, however, the extraction parachutes contacted the ground and skidded for approximately 60 feet while opening. The plastic molding on the rope where the Army clevis attached was chipped, probably due to ground impact after breakaway. A set of intermediate conveyor frame assemblies was bent,probably due to being struck by the extraction line during deployment.

TEST 21

This was the first LAPES airdrop test. The test configuration was a 15RS drogue parachute and two 35R extraction parachutes. An 80-foot-long line of MIL-W-4088,Type XXIII (12,000 pound) webbing was used to keep the drogue attached. Previous tests with the attached drogue used two 98-foot long 12,000 pound nylon lines. This change was made in order to shorten the system.

The extraction parachutes skidded along the ground approximately 15 feet while opening. They continued to open and extracted the load safely. The load impacted the ground 360 feet beyond the impact panels. The load stopped approximately 770 feet from the impact point. The wheel heights were 18 and 5 feet at the release and impact panels respectively. The V-bridle clevis tie to the ACB broke at snatch force,but the clevis did not strike the ramp. There was no damage. It was decided not to change the V-bridle clevis tie on future tests because there was no damage and because further strengthening of this tie could be detrimental to the structure of the existing ACB and complicate

the method used to secure the ACB to the load.

TEST 22

The only difference from the previous test was that seven aircraft restraint locks were set at a setting of 4.0 (versus eight locks at 4.0 as on test 21). This test was conducted to check the repeatability of the previous test and to determine the suitability of using lower lock restraint.

All subsystems operated normally. There was no aircraft damage and the parachutes did not contact the ground during deployment. The load impacted the ground 246 feet past the second set of panels and skidded 471 feet before stopping. The wheel heights at the release and impact panels were 25 and 7 feet respectively.

The following extraction system damage was found: on several tie loops their stitching was pulled loose from the bag; the extraction line had several burned places, probably due to drogue line contact; the drogue line was badly burned on both edges; and both extraction parachutes had burns in their apex area and broken stitches on a few ribbons.

TEST 23

The only change from the previous test was that the load weight was increased to 42,000 pounds. The test was conducted to gather data on the effect of additional weight on the operation of the system.

All subsystems operated normally. The forward part of the tow plate cover was slightly dented by contact with the padded 4-point clevis,however there was no damage to the tow plate mechanism itself. One of the two extraction parachutes opened slowly but appeared to reach a full open condition prior to load exit. The extraction system did not contact the ground during deployment. The load impacted the ground 375 feet past the impact panels and skidded 738 feet before stopping. The wheel heights at the release and impact panels were 18 and 10 feet respectively.

TEST 24

This test condition differed from the previous one in the following ways: it was a low velocity airdrop the load weight was 35,000 pounds, the lock setting was seven locks set at 3.5, and the 35R adapters were shortened from 24 to 10 feet (USANC drawing No. not available). This test was conducted to determine the effect of the shortened adapters on system performance.

All subsystems operated normally. There was no damage. The adapters made no discernable change to system operation.

TEST 25

In this test a lower lock setting was used (7 locks at 3.25 versus 7 locks at 3.5). One of the two extraction parachutes opened slowly , reaching full open at approximately force transfer, otherwise the test was uneventful.

It is interesting to note that the snatch force obtained during LAPES was only about half the snatch force obtained during airdrop and that the snatch force was not related to the size of the parachute used as the drogue. Reasons for the snatch force being lower during LAPES are that the V-bridle clevis tie to the ACB accelerates the system somewhat prior to breaking , and that the play-out of the LAPES V-bridle cushions the remaining snatch force. On a low velocity airdrop, the extraction line is attached directly to a single point on the load with no intervening comparable break tie or V-bridle to absorb energy.

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APPENDIX C

PACKING AND RIGGING PROCEDURES

PACKING THE 60-FOOT ROPE EXTRACTION LINE AND

80-FOOT DROGUE LINE IN THE LINE BAG

Stretch rope by hand, and inspect. Measure length of rope from end to end and circumference at three places: 1/4,1/2, and 3/4 the distance from one end. Inspect the drogue line.

Position bottom panel of line bag, with stow loops up, on a packing surface (Figure C1). Girth hitch as necessary to the stow loops pieces of MIL-W-5665,Type II,575 pound capacity cotton webbing (575). With approximately three feet of rope extending from the lower right hand corner of the bag panel, run the remaining rope up the right side, aligning the rope with edge of panel and across the top of the panel (Figure C1). Make three equally spaced ties to the right side stow loops and one on the top middle stow loop. Make positive ties with surgeons and locking knots (Figure C1).

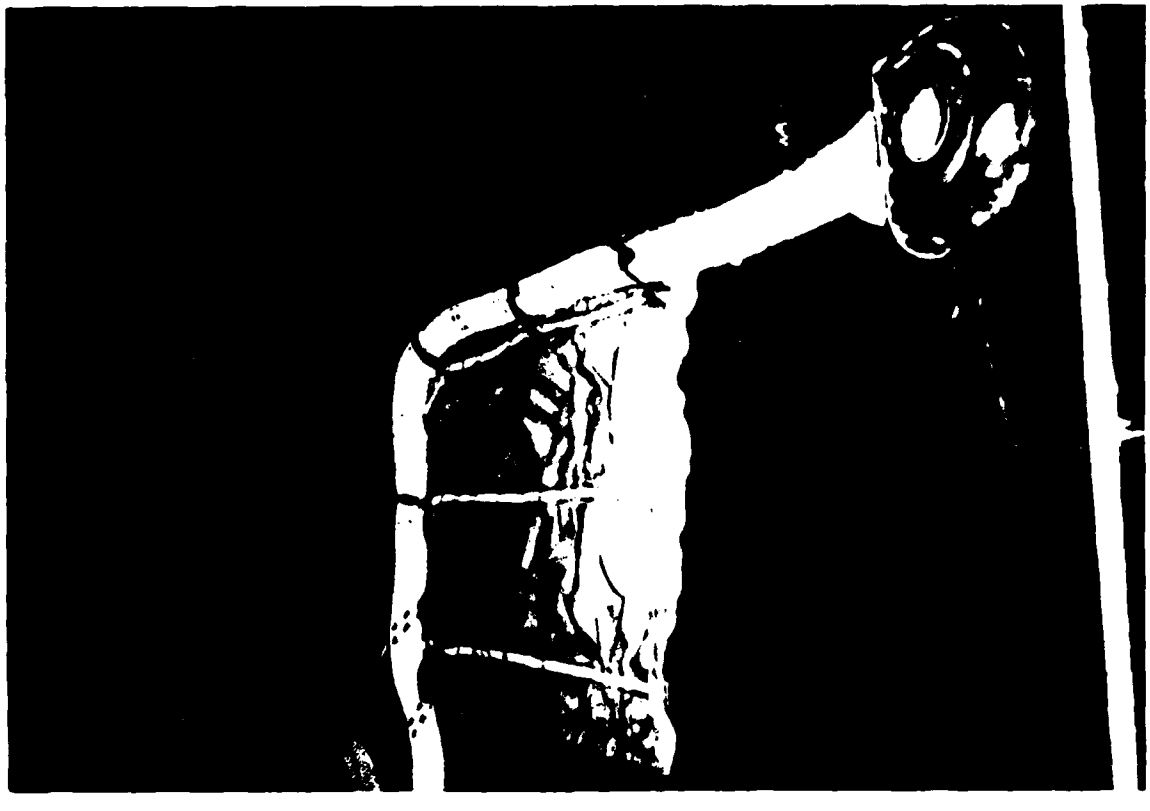


Figure C1
Bag Bottom Panel

Continue stowing by S-folding rope from left to right by starting in the upper left hand corner. Make ties around single leg of rope (Figure C2).

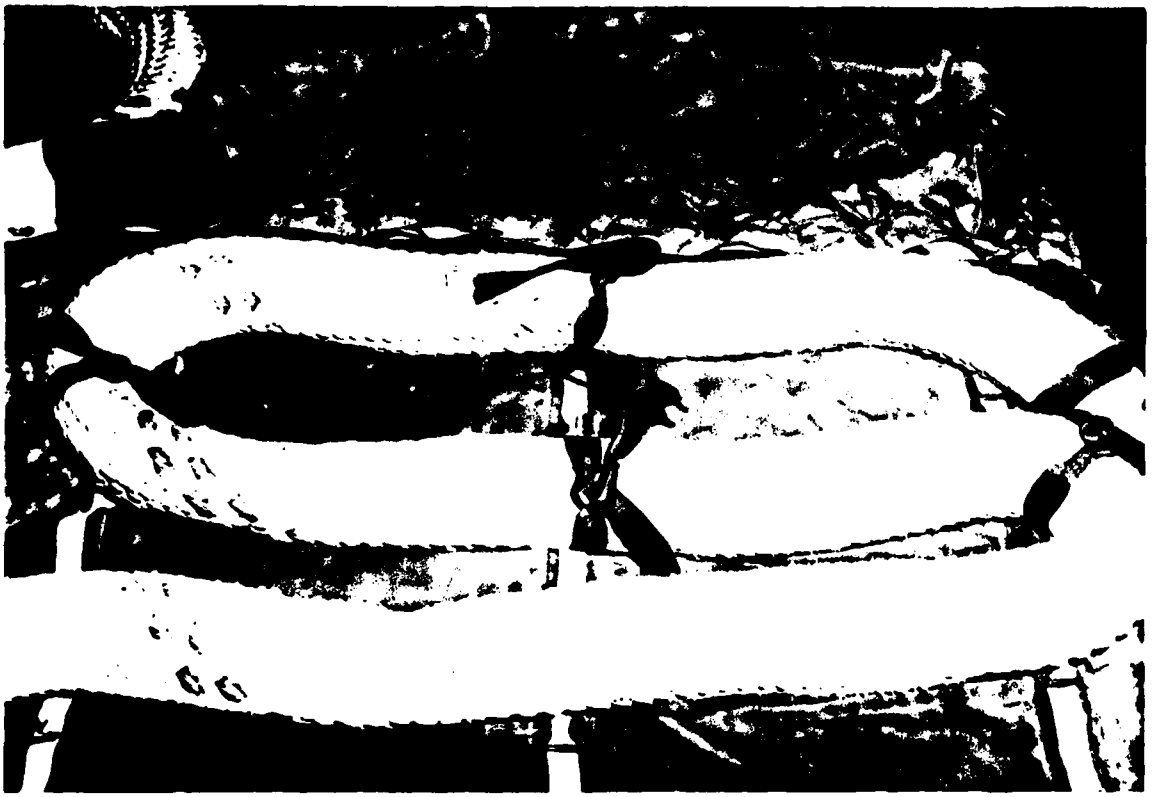


Figure C2
Rope Stow Ties

All stow loop ties are made around single leg of rope until approximately seven feet remains out the lower left panel corner (Figures C3,C4).

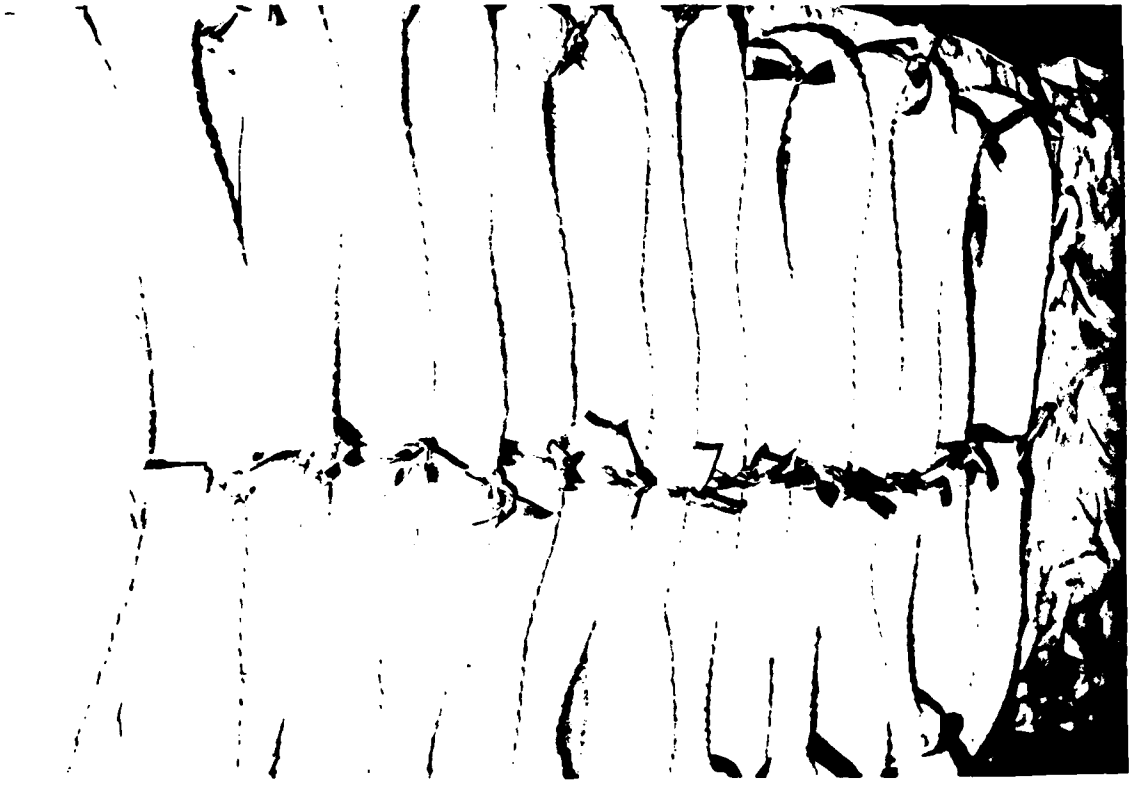


Figure C3 Rope Stowed on Panel

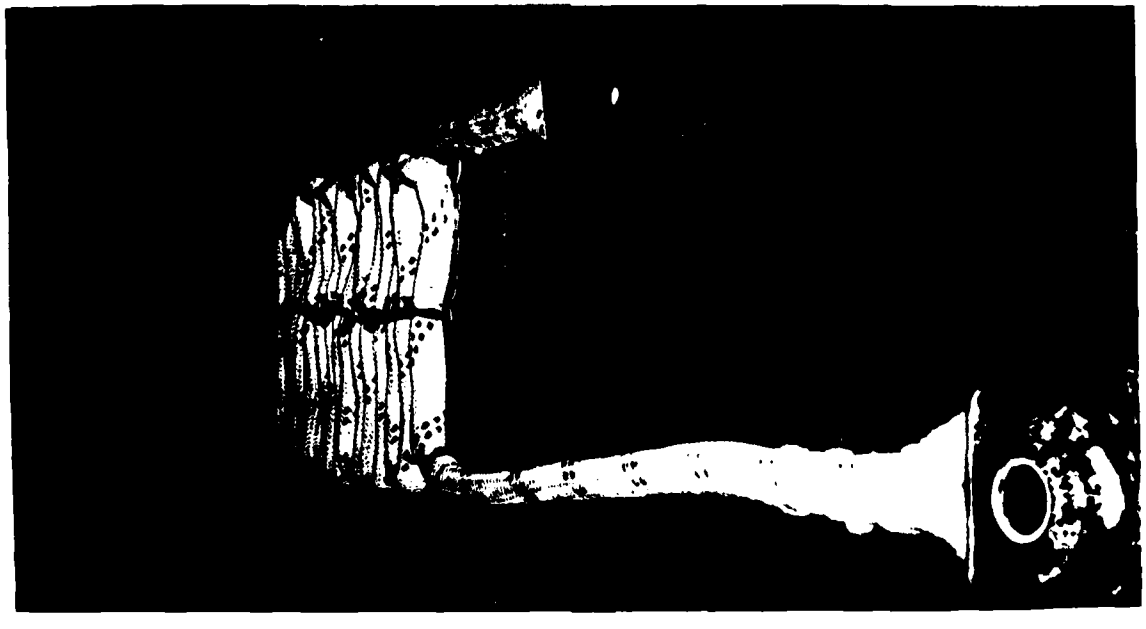


Figure C4
Ends of Rope

Place a second line bag panel above the rope with stow loops down. Attach a bag bridle using procedures described in T.O. 13C5-1-102, page 2-104 G,paragraph 2-105.14 , Figure 2-202 K. Pull one end of drogue line between the two panels at the center point. Position the end loop at a point approximately three feet beyond the upper edge of the panel in line with the loop in the bag bridle.

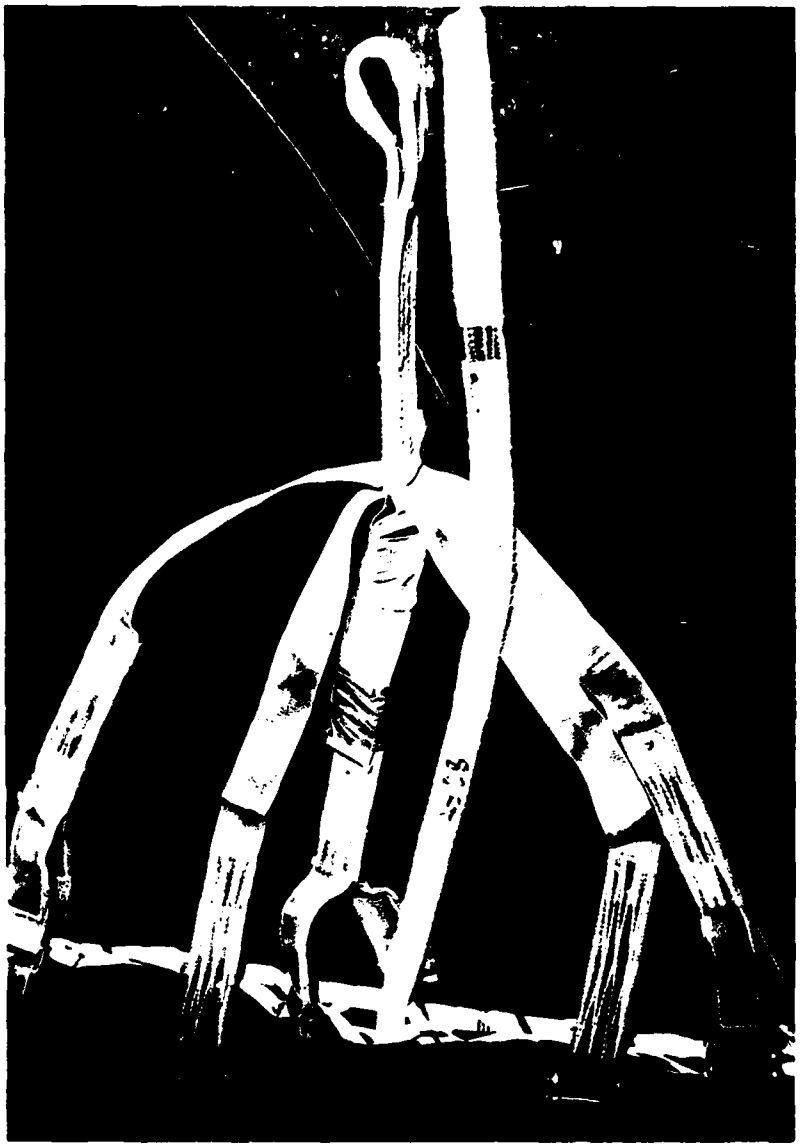


Figure C5
Drogue Line Alignment

Fold the second panel back over the bag bridle (like turning a page in a book). Secure the drogue line to first stow loop in the middle row of the panel with a single turn of MIL-T-5661,Type I, 1/4 in wide, 80 pound cotton tape (80) (Figure C6).

Figure C6
Drogue Line Secured to Panel

Pass drogue line across the upper part of the panel to the right side and secure loop of drogue line to the top side stow loop with a single turn of 80 (Figure C7).

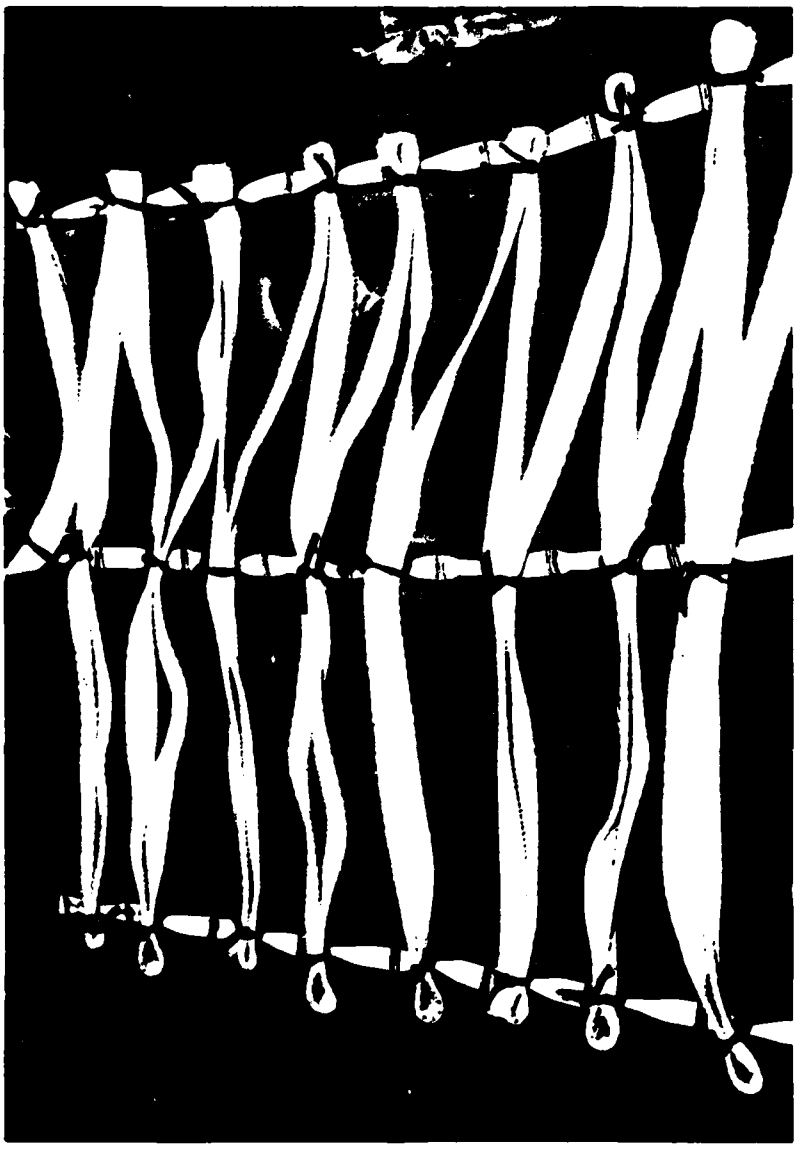


Figure C7
Drogue Line Stow Ties

S-fold remaining drogue line and tie at each row of stow loops until approximately three feet of line extends beyond lower left side of panel (same side as the 3 foot end of the rope),(Figure C8).

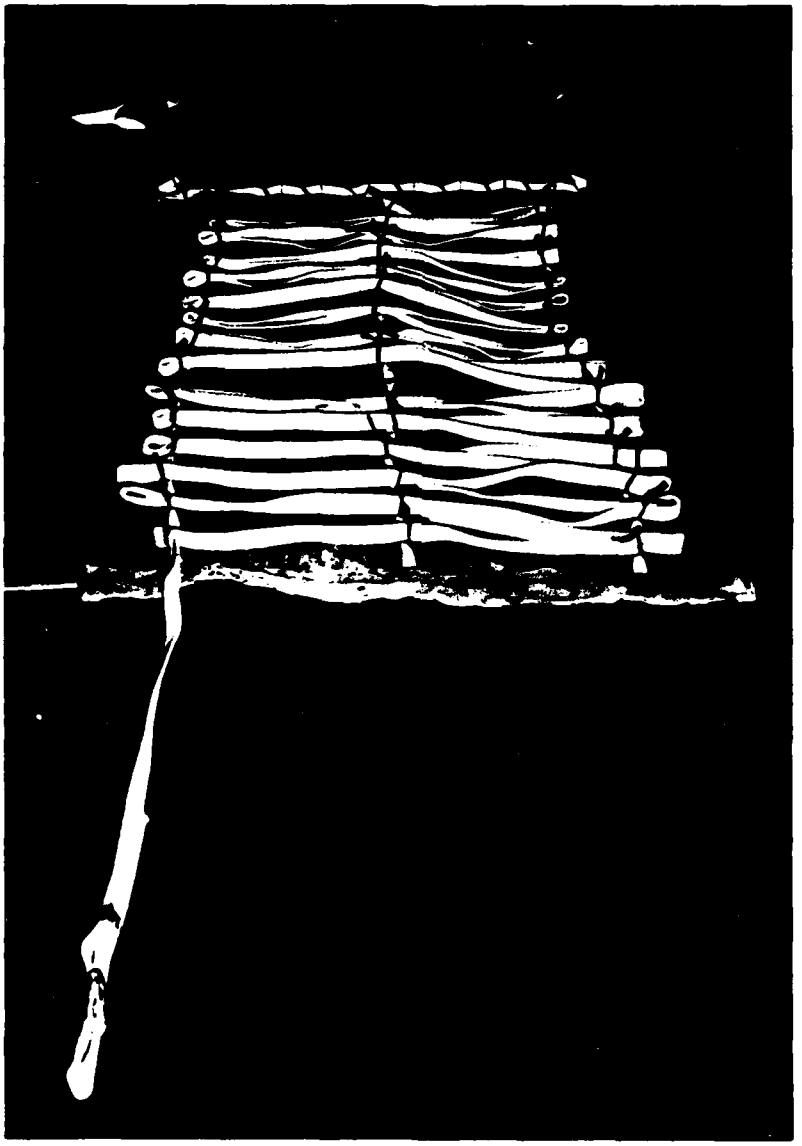


Figure C8
Drogue Line Stowed on Second Panel

Place a third panel on top of the stowed rope on first panel (This third panel will end up as middle panel)(Figure C9).

Figure C9
Third Panel Atop the Stowed Rope

Fold the second panel (with drogue line attached) over top of third panel and align ends of all panels. Tie sides of bag with one turn of single 80 incorporating V-loops of all three panels (Figure C10), at four places on each side (Figure C11). Lace bridle end of bag with one turn of MIL-W-5625, 1,000 pound tubular nylon, incorporating all three panels.

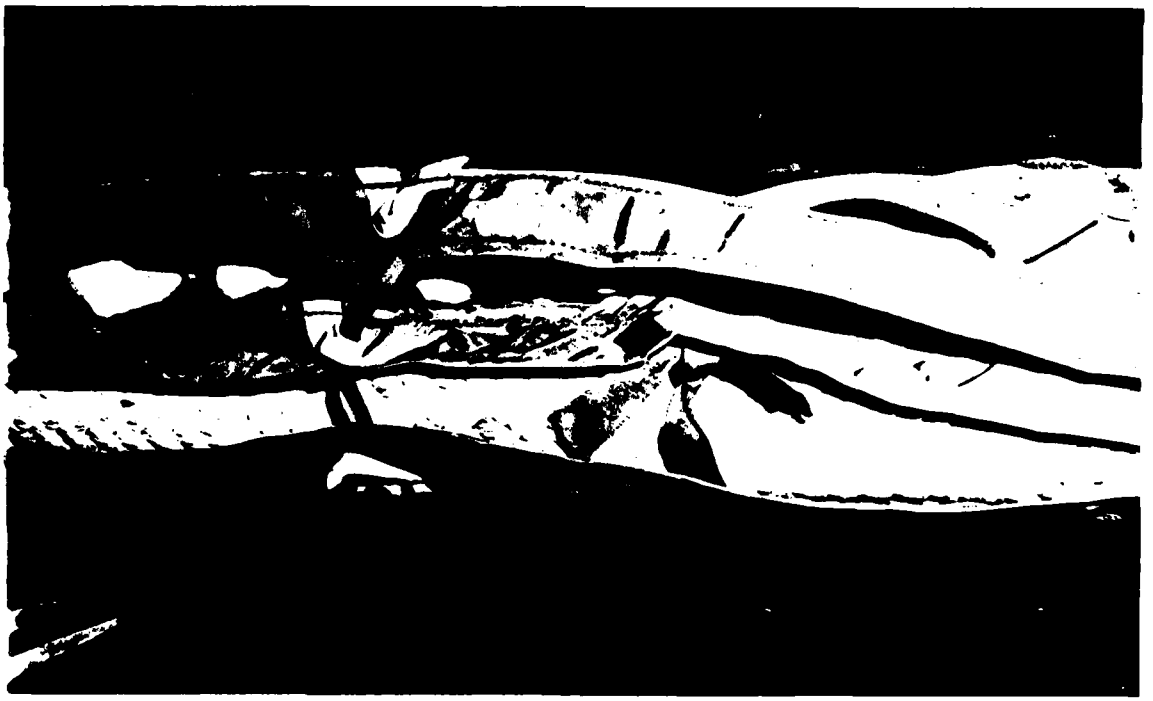


Figure C10 Incorporation of V-Loops

Lace the bag mouth (opposite bridle end of bag) closed with a piece of doubled 80 by attaching one end of the 80 to the top panel, left or right side, rout the 80 down to bottom panel (outside of rope), then under the rope and up to the top panel, then down to the bottom panel (Figure C11).

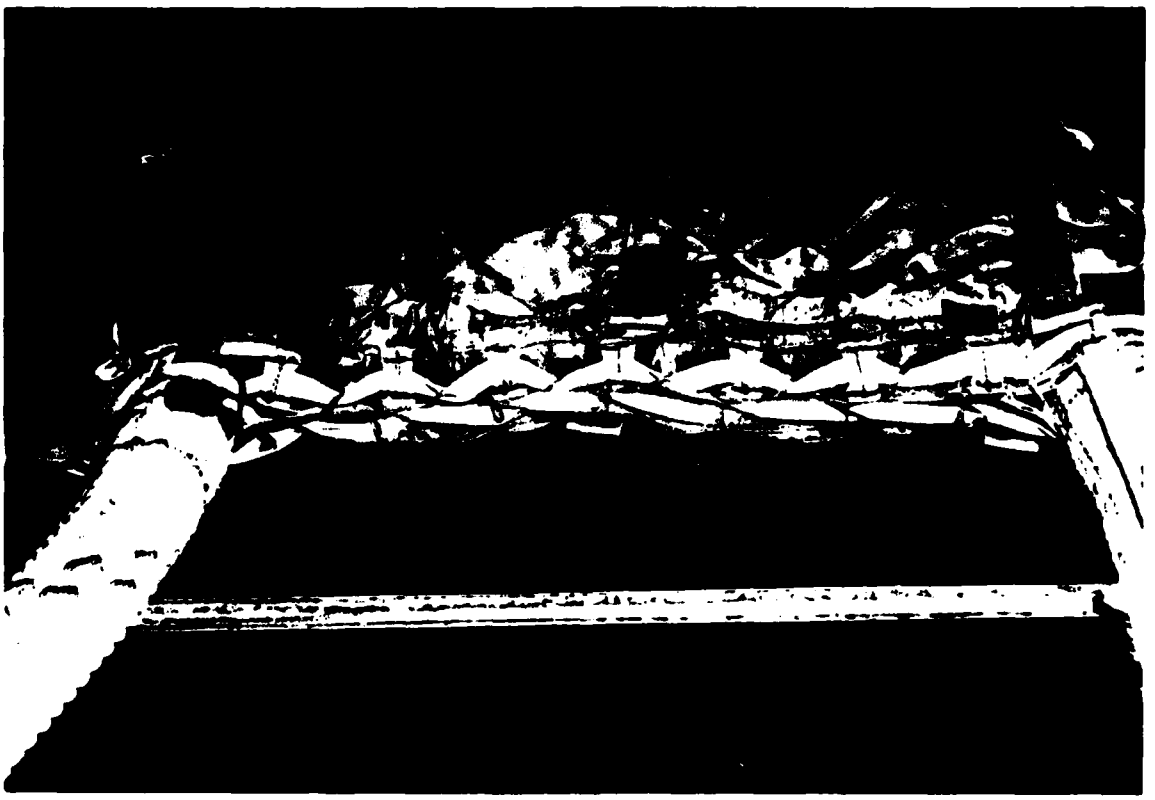


Figure C11
Closed Bag Mouth

Continue lacing bag closed in like manner. Secure free end to the last lace with two half-hitches. The 3 foot ends of rope and drogue should exit the bag on same side. The loop of drogue line will match up with loop of the rope (Figure C12).

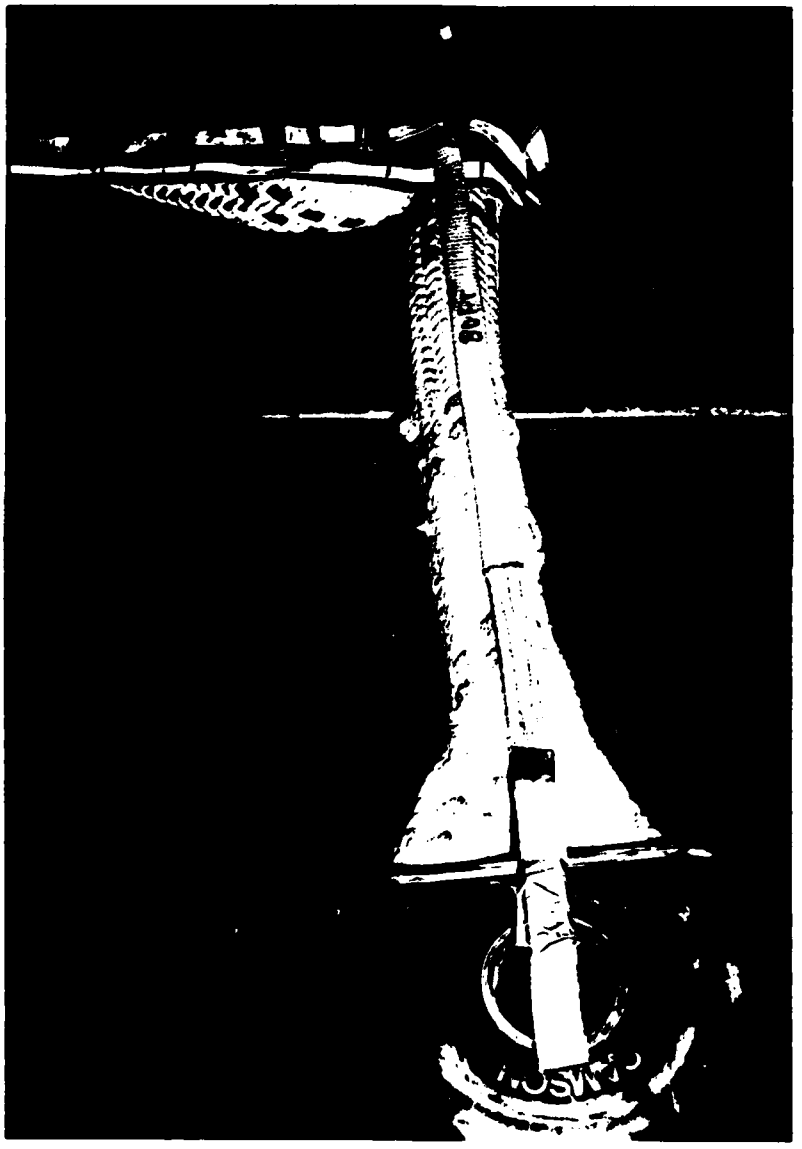


Figure C12
Three Foot End of Rope and Drogue Line

PACKING THE 35-FOOT DIAMETER RIBBON EXTRACTION PARACHUTE

Folding Gores and Longfolding Canopy:

Longfold the canopy per instructions contained in TM 10-1670-215-23, paragraphs 2-99 and 2-100, bearing in mind that this canopy has 48 gores and 48 suspension lines (Figure C13).

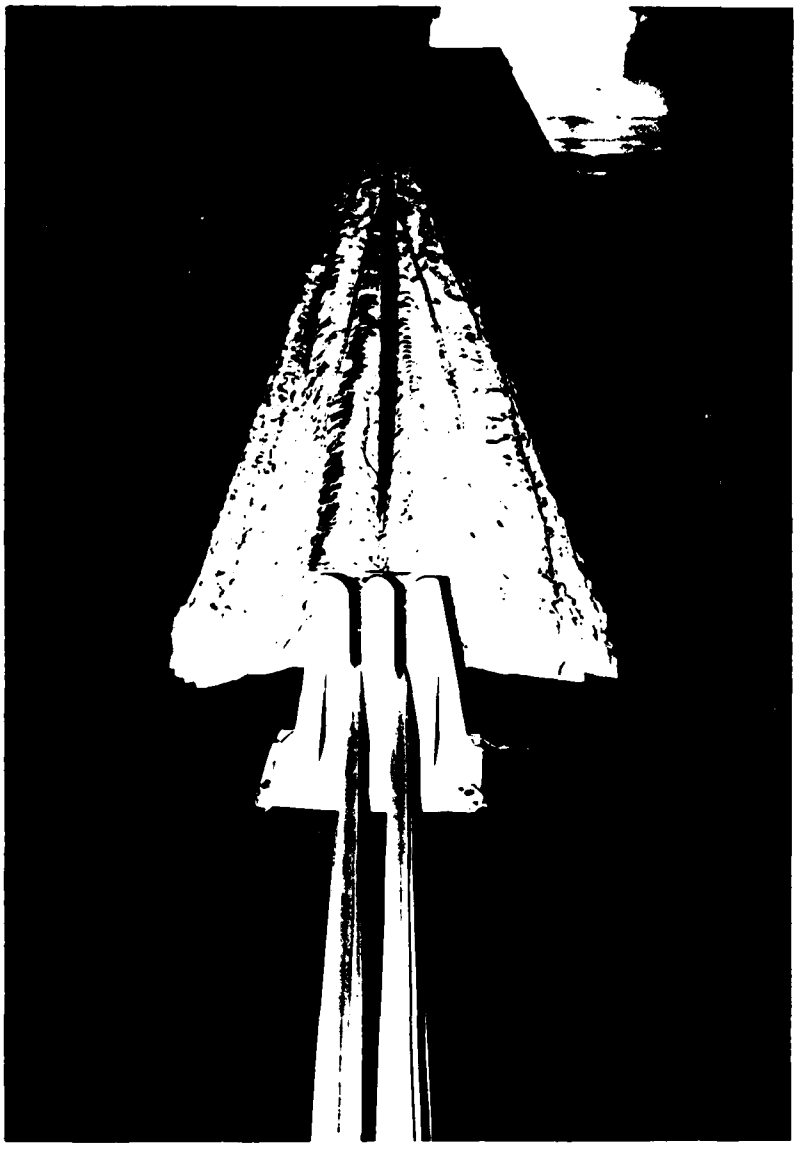


Figure C13
Longfolded Canopy

Atacching the Deployment Bag:

a. Place the mouth of the deployment bag at the canopy bridle loop.

b. Pass a piece of 550 pound, equal to twice the length of the bag, through the canopy bridle loop (Figure C14).

c. Pass both free ends of the 550 pound through the bag end slot and around the bag bridle straps. Secure with a surgeons knot, locking knot, and an overhand knot.

Figure C14
Attaching the Deployment Bag

Stowing the Canopy:

a. With the canopy laid out (Figure C15) make the first canopy stow in the inside right corner of the deployment bag. Make the second stow in the inside left corner of the bag and continue to make S-fold stows across the width of the bag until the canopy is completely stowed.

b. Make one stow, folding the suspension lines from left to right across the stowed canopy.

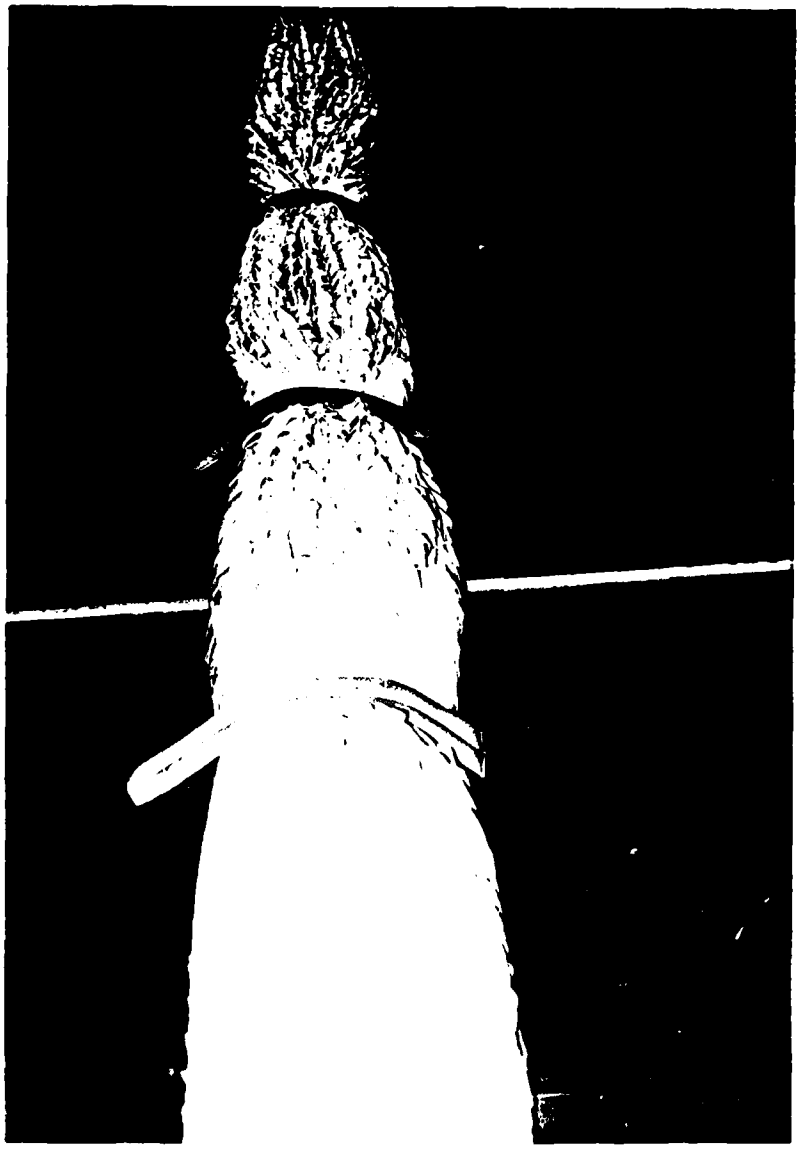


Figure C15
Canopy Ready for Stowing

Stowing the Canopy (Continued):

c. Pass a suitable length of 80 under the suspension lines, through the two bag inside flap loops, and across the top of the suspension lines. Tie with surgeon's and locking knots(see Figure C16).

Figure C16
Inside Bag Loop Ties

Stowing the Remaining Length of Suspension Lines:

a. Lay the bag down with stow flap on top of the bag and girth hitch a suitable amount ties of 80 along the stow loops located on the deployment bag suspension line stowage flap.

b. Form the first suspension line stow at the upper right corner of the stowage flap and secure with a surgeon's knot and locking knot .

c. Next, form and secure the second suspension line stow in the upper left hand corner of the stowage flap.

d. Continue stowing the suspension lines on the stowage flap from left to right alternately until the last stow, which is secured at the lower left hand corner of the stowage flap, within approxomately 2 1/2 feet of the adapter connector links (Figure C17).

e. Tape connector links with masking or cloth tape.

Figure C17
Stowing Suspension Lines

Closing the Deployment Bag:

a. Flip the bag so that the stowage flap lays on the floor in front of the deployment bag with enclosed canopy (Figure C18).

b. Position the taped suspension line connector links in the upper center of the stowage flap next to the canopy skirt by bringing the suspension lines up and across the stowage flap from left to right (Figure C18). Insure that the adapter web extends from the left side of the bag.

Figure C18
Stowage Flap on Floor

Closing the Deployment Bag (continued):

c. Tightly roll the suspension line stowage flap and tuck into the mouth of the deployment bag.

d. Tuck in the right end flap and position the adapter web lengthwise from left to right across the rolled suspension line stowage flap.

e. Make a temporary bag closing tie by criss-crossing a suitable length of 80 through the four bag closing loops and tie closed (Figure C19).

Figure C19
Temporary Bag Closing Tie

Stowing the Adapter Web:

a. Lay the deployment bag side flaps back on the floor and bring the adapter web from the lower right up and across the bag to make the first stow in the upper left corner of the deployment bag with single tie of girth-hitched 80. Tie with surgeon's knot and locking knot.

b. In like manner, make the second stow in the upper right corner of the bag. Continue stowing until the final stow is made in the lower left corner with approximately 2 feet of adapter web extending from the bottom of the deployment bag (Figure C20).

Figure C20
Adapter Web Extending from Deployment Bag

Closing the Adapter Web Flaps:

a. Extend the left adapter web closing flap from left to right across the adapter web and pass a suitable length of 550 through the upper left adapter web flap closing loop and the upper right bag loop (1 turn single). Secure with a surgeon's knot, locking, and overhand knots (Figure C21).

b. In like manner, extend and tie the right adapter web closing flap from right to left across the other flap (Figure C21).

Figure C21
Adapter Web Flaps Closure Ties

Permanent Bag Closing:

a. Prepare a miniature cutter knife (LAPES knife, PN71172) by passing one turn double ticket No. 5 cotton thread through the holes in the sides of the cutter knife. Secure with surgeon's and locking knot. Attach a ten foot length of 1,000 pound for a lanyard using a square knot and overhand knot in the short end.

b. Replace the temporary 80 bag closing tie with 1/2inch tubular 1,000 pound breaking strength nylon webbing (1,000) cut to a suitable length.

c. Pass the 1000 through lower left bag closure loop from inside out. Pass end vertically up and through both the adapter flap loop and the upper left bag closure loop.

d. Pass both ends of 1000 through knife between safety and the lanyard end of the knife. Pass the end of the 1000 that originated at the lower left through the bag closure loop then the adapter flap loop at the upper right. Pass the other end of the 1000 through the lower right bag closure loop. Secure ends of the 1000 with surgeon's and locking knots so that the 1000 forms a figure eight with the knife in the middle (Figure C22).

Figure C22
Permanent Bag Closure Ties

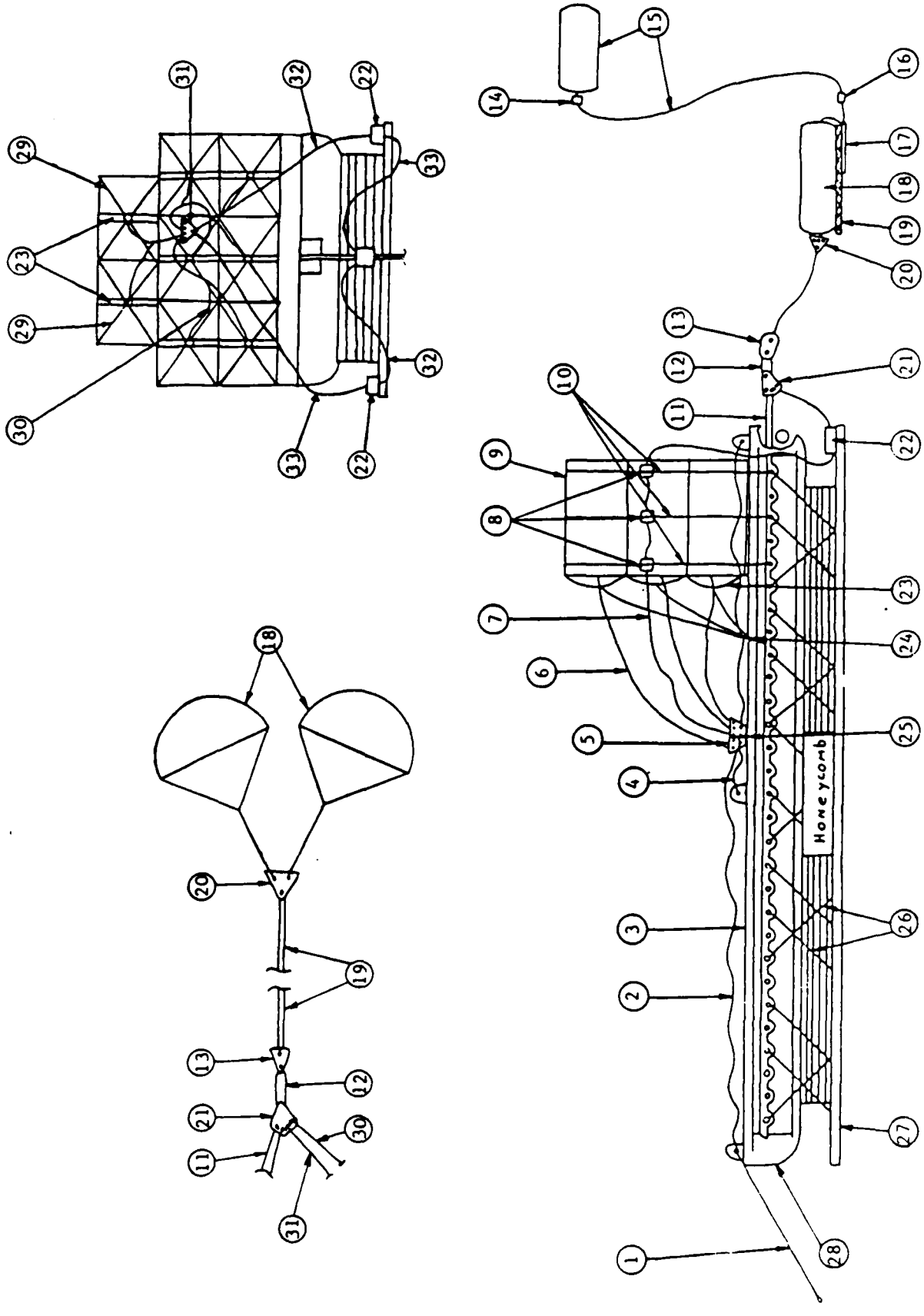


Figure C23
Low Velocity Airdrop Rigging Sketch

Figure C23 (Continued)

1. Guillotine force transfer lanyard, Mil-W-4088 Type XVIII (6,000 pound),floor line activated,secured to floor line ring with two turns of Mil-C-5040 Type III (550). Secure ring to a chain on forward end of platform with two turns of Mil-T-5661 Type I (80) forming a drag tie.
2. Suspension slings 24 feet , 8 ply of Mil-W-4088 Type XXVI, 4 ea. , stow and tie with double 80.
3. Cover tub w/honeycomb and secure.
4. Suspension slings 21.5 feet, 8 ply of Type XXVI, 2 ea., stow and tie with double 80.
5. Suspension load coupler block, 16 spools (local drawing No. 68D1487).
6. G-11A cluster risers (8 ea.), 6 ply of Mil-W-4088 Type X, 120 feet long.
7. Shaw knife lanyard, 6,000.
8. Shaw knife, 3 ea. three places, safety tie with one turn of 80.
9. G-11As (8 ea.) on honeycomb tray.
10. Parachute restraint, 6,000 (3 places).
11. Cutter web, 5-Foot-long, Type XXVI, 12 ply.
12. Strain link, 70K (local drawing No. X829039) or, 100K (local drawing No. X829029)] and swivel (local drawing No. 83C010), see Figure C24A.
13. Two point clevis (local drawing No. X829075), see Figure C25C.
14. Clevis, 25,000 pound capacity (black clevis, local drawing No. 66C1406).
15. Drogue parachute (15 Foot dia.RS) and extraction line (60 feet long), P/N 6184312.
16. Tow plate link.
17. LAPES tow plate.
18. Extractionparachute(s) (i.e. 2 ea.35 Footdia.Ribbon),see Figure C26.
19. Extraction line, 7.5 inch circumference rope (contained in line bag), see Figure C11.
20. Four point clevis (Army clevis , USANC drawing No. X11-1-2941), see Figure C27.
21. Five point clevis (local drawing No. 68D1480), see Figure C24B.
22. Koch device (go/no-go , 2 ea.), tie to platform with 4 turns 550, 2 ties fwd. 2 ties aft, see Figure C28.
23. Belly band, Type XXVI, 78 inch long.
24. Shaw knife and lanyard (6000 pound), insert belly band through it.
25. Load coupler tie, restraint to tub with 1 turn 6000 pound.
26. Restraint, chains and devices (20 fwd. 10 aft.).
27. LAPES platform, A/E 29H-1, 24 feet long.
28. Weight test platform, twenty four feet long, with guillotine knife, 35,000 pounds gross extracted weight. Center weight in tub.
29. G-11A bag bridles.
30. Y-risers, 7 feet long, connect to G-11A bag bridles.
31. Four-to-one clevis (local drawing No. 77C1748), three plates. Connect to single end of Y-risers.
32. Deployment line, 6 ply Type XXVI, 12 to 16 feet long.

Figure C23 (Concluded)

33. Deployment line, 6 ply Type XXVI, 6 to 8 feet long.

Note: 1. Koch device will be armed by 3 feet long static line to side of aircraft.
2. Load restraint criteria = 4 G's fwd., 2 G's aft.
3. Tie all G-11As together at each corner with one turn 550.

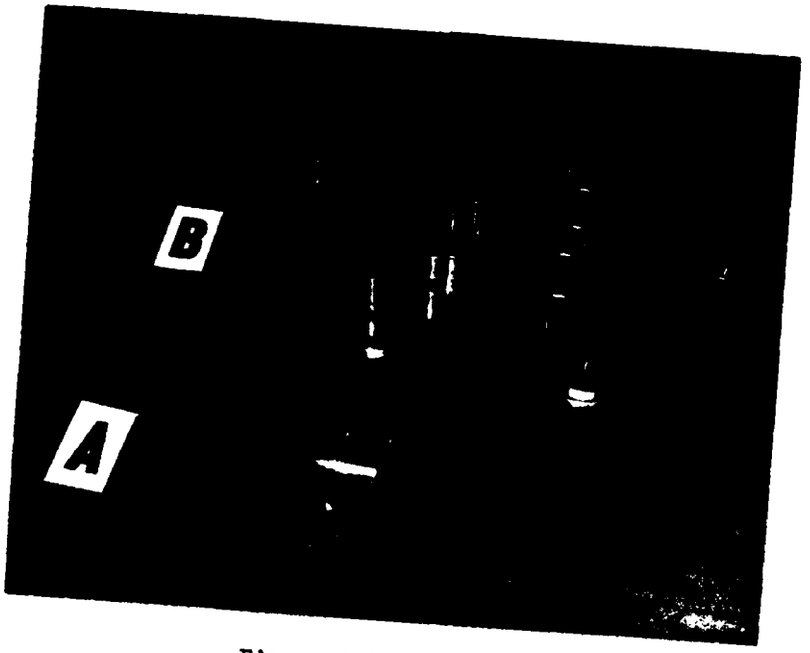


Figure C24 Hardware
A. Strain Link Swivel (Drw # 83C010)
B. Five Point Clevis (Drw # 68D1480)

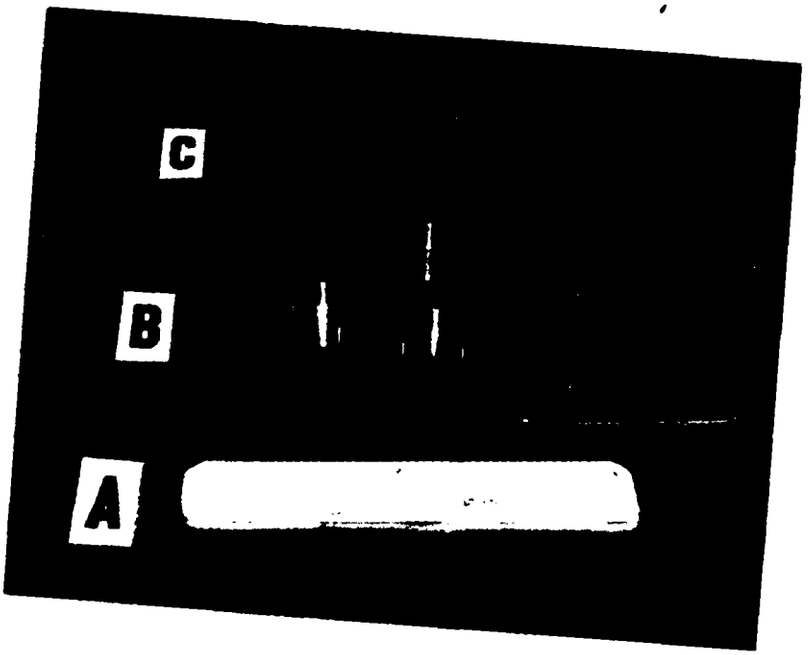


Figure C25 Hardware
A. Plates, Connecting Platform, Heavy Duty (100K Pounds, Drw # 67C1416-1)
B. Three Point Clevis (Drw # X829078)
C. Two Point Clevis (Drw # X829075)

Figure C26
Parachutes Rigged in Aircraft

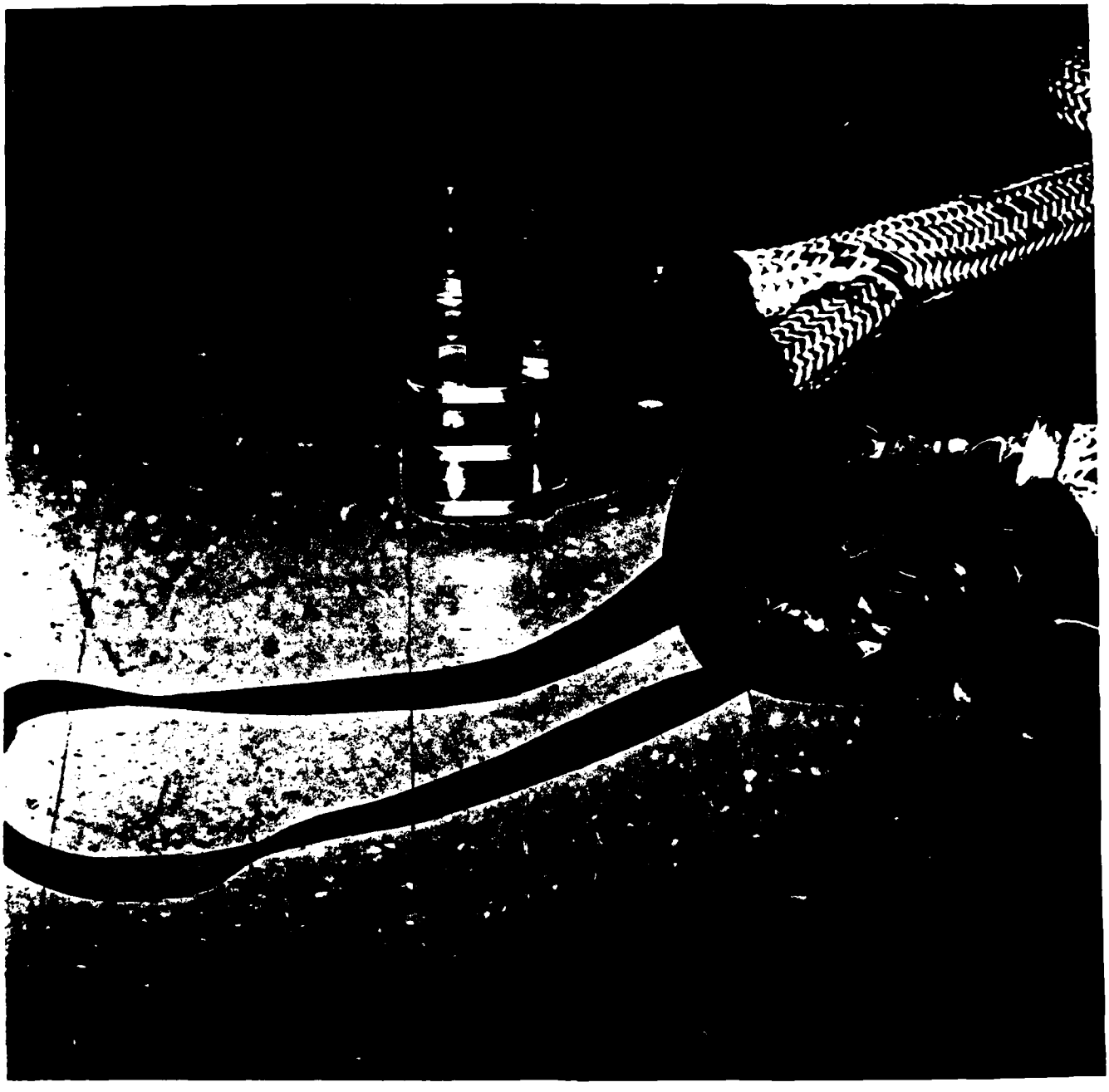


Figure C27
Army Clevis and Inflation-Break Weak Link

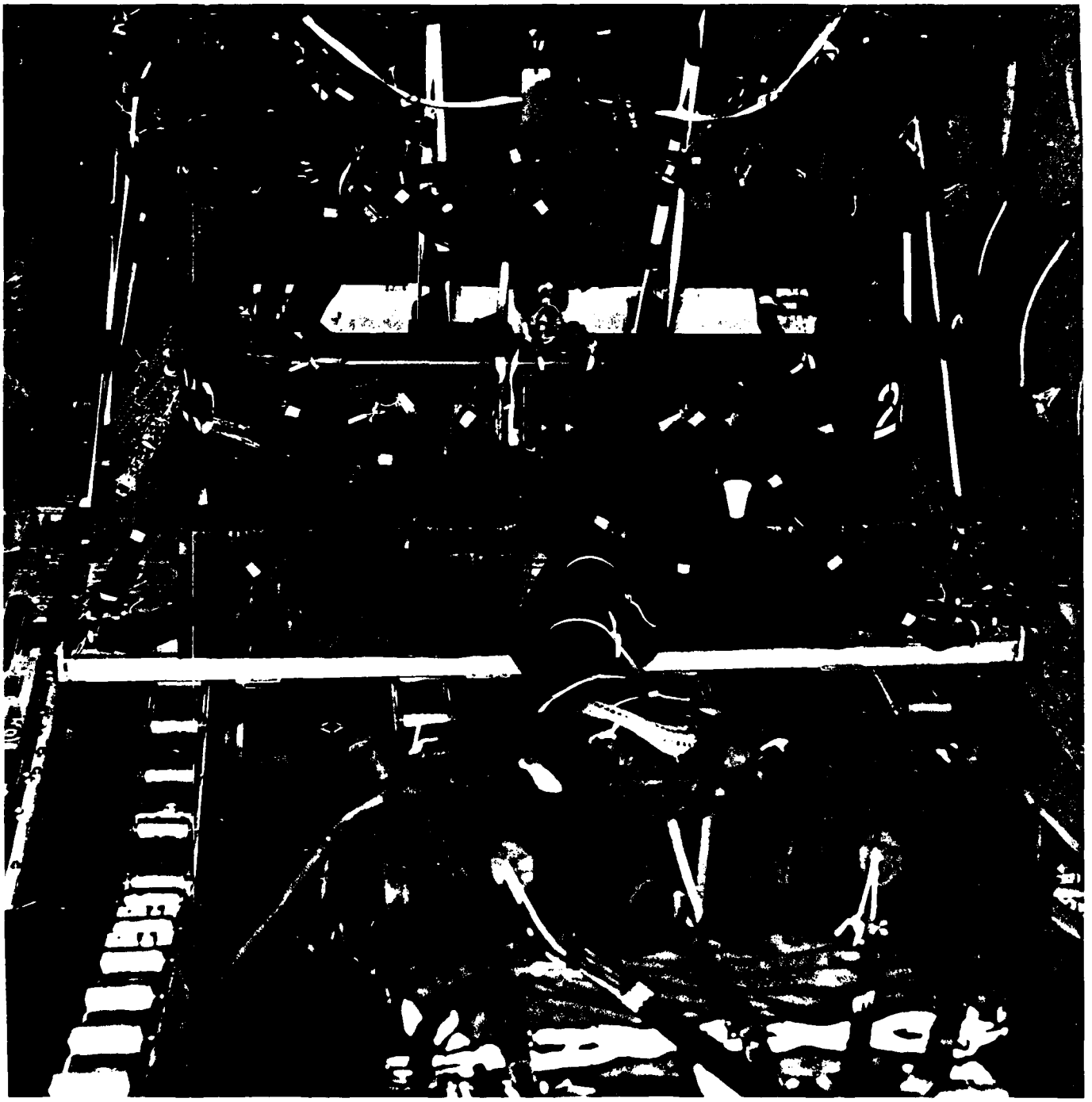
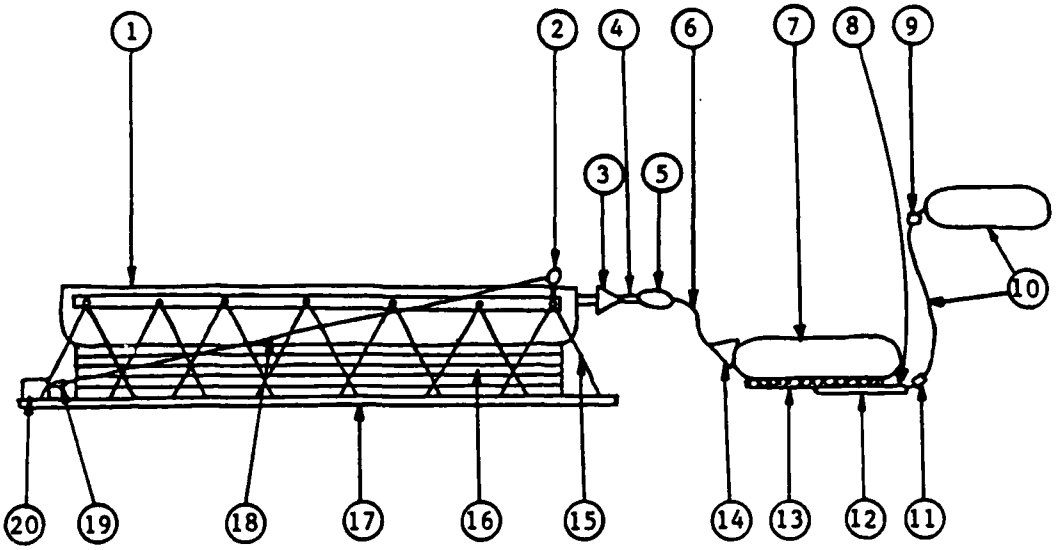


Figure C28
Rigging for Two Go-No-Go Devices



1. Weight-test platform.
2. ACB ,see Figure 2.
3. Three point clevis (local drawing No. X829078) , modified to 4 points to accept ACB ties,felt padded and secured to ACB with three turns of Mil-W-4088 Type XVIII (6,000 pound.)
4. Strain Link (100K, local drawing No. X829029) and swivel (local drawing No. 83C010), see Figure C24A.
5. Two point clevis (local drawing No. X829075), see Figure C25C.
6. Extraction line, 7 1/2 inch circumference rope,(contained in line bag), see Figure C11.
7. Extraction parachute(s) (i.e. 2 ea. 35 Foot diameter, ribbon), see Figure C26.
8. Bag bridle and drogue line (USANC drawing No.s 11-1-2593 and 11-1-3213).
9. Clevis , 25,000 pound capacity (black clevis , local drawing No. 66C1406).
10. Drogue parachute (i.e. 15RS) and drogue line (60 feet, 12 ply), P/N 6184312.
11. Tow plate link.
12. LAPES tow plate.
13. Extraction line bag, see Figure C11.
14. Four point rope clevis (Army clevis, USANC drawing No. X11-1-2941), see Figure C27.
15. Load restraint, 12 G's forward, 6 G's aft.
16. Paper honeycomb,3 inch, 5 layers.
17. LAPES platform, A/E 29H-1, 24 feet long.
18. Extraction V-bridle, 2 legged, (2) 32 feet long, Type XXVI, 12 ply.
19. LAPES clevises (local drawing No. 83C004), two required.
20. Plates, connecting platform (4 ea.), heavy duty (100,000 pound., local drawing No. 67C1416-1), see Figure C25A.

Figure C29
LAPES Rigging Sketch

APPENDIX D

TABLE D1

EXTRACTION LINE CIRCUMFERENCE AND LENGTH HISTORY

LINE NO.	PRIOR TO PACK FOR TEST NO.	LENGTH[1] (FT-IN)	CIRCUMFERENCE[2] 1/4	1/2	3/4
1	1	157-9	8.50	8.50	8.50
4	2	154-1	10.00	10.00	10.00
5	3	139-6	9.00	9.00	9.00
6	4	141-9	9.00	9.00	9.00
A	5	63-5	9.00	9.00	9.00
B	6	64-4	9.00	9.25	9.25
B	7	64-4	9.00	9.25	9.25
B	7a	66-0	8.75	8.75	8.75
B	8	68-6	8.25	8.25	8.25
B	16	67-0	8.25	8.25	8.25
B	17	68-9	8.25	8.25	8.25
B	18	68-9	8.25	8.25	8.25
B	20	67-6	9.00	9.00	8.50
B	20a	67-4	8.50	8.50	8.50
B	21	66-10	8.50	8.50	8.50
B	22	66-11	9.50	9.50	9.50
B	23	67-2	8.50	8.50	8.25
B	24	66-3	8.50	8.50	8.50
B	25	66-1	8.75	8.75	8.75

APPENDIX D

TABLE D1 (Concluded)

EXTRACTION LINE CIRCUMFERENCE AND LENGTH HISTORY

LINE NO.	PRIOR TO PACK FOR TEST NO.	LENGTH[1] (FT-IN)	CIRCUMFERENCE[2] 1/4	1/2	3/4
C	9	63-8	10.00	10.00	10.00
C	10	65-10	10.00	9.75	9.50
C	11	65-6	9.50	9.50	9.50
C	12	65-6	10.00	10.00	10.00
C	13	65-1	10.00	10.00	9.50
C	14	65-2	9.75	10.00	9.50
C	15	65-4	10.00	10.00	9.75

1. Measured stretched out on a table under no tension.

2. As requested by USANC-STRNC-UAS the circumference was measured at three places: 1/4, 1/2, and 3/4 of the total length from one end.

LIST OF ABBREVIATIONS AND SYMBOLS

Item	Definition
ACB	attitude control bar
ADS	air delivery system
AFFTC	Air Force Flight Test Center
AFR	Air Force Regulation
AGL	above ground level
BS	breaking strength
CG	center of gravity
DEG	degrees
Do	nominal diameter
Drw	drawing
FS	fuselage station
G-11A	100 Foot diameter recovery parachute
KIAS	knots indicated airspeed
LAPES	low altitude parachute extraction system
LZ	LAPES zone
MSL	mean sea level
No.	number
OAT	outside air temperature
R	Ribbon
RS	Ring Slot
SS	Single Slot
TIT	turbine inlet temperature
TM	telemetry
TS	Test Squadron
TSS	Test Support Squadron
USANC	U.S. Army Natick Research and Development Center